THE PROCEEDINGS

of the

Institute of Medicine of Chicago

Vol. 3 No. 2

CHICAGO
1921

TWENTIETH CENTURY CONTRIBUTIONS TO OUR KNOWLEDGE OF THE ATOM

R. A. MILLIKAN
University of Chicago

April 16, 1920

I shall not enter into the discussion of controversial matters, and there are many of them in this field, but shall rather pass in simple review the extraordinary developments of the last twenty years which have thrown an enormous amount of new light on our knowledge of the atom and its behavior.

We may properly characterize the physics of the last twenty years as the physics of atomism. The physics of the last century could perhaps be characterized as primarily the physics of the ether, although the atomic theory and experimentation in the field of the atomic constitution of matter did play something of a rôle in nineteenth century developments. When, however, one remembers that the first great discovery of the nineteenth century, made in the year 1802, was the discovery by Thomas Young of the interference of light—a discovery which established the undulatory theory; and when one remembers that the most prominent name in the first half of the nineteenth century was that of Faraday, whose greatest contributions concerned the discovery of specific inductive capacities and their relations to electric charges; and when one remembers further that the most prominent name of the last half of the nineteenth century was that of Maxwell, and that Maxwell's great contributions consisted in an extraordinarily penetrating analysis of Faraday's experiments, and in the development of the theory of electric magneto waves; and when one remembers that Maxwell was followed by Hertz, who experimentally verified the Maxwell theories; and finally when one recalls that the last years of the nineteenth century were pregnant with new discoveries in wireless telegraphy, all in this same field, he begins to realize what a large fraction of our work in physics during the last century was associated with the phenomenon of the transmission of energy through space, or if you prefer, through ether. We might just as well call it ether as space in spite of the protestations of the relativists.

The twentieth century has been characterized by an entirely different group of experiments and discoveries—discoveries which have appeared at a rate altogether unparalleled in the history of the world. Most of these developments have concerned the giving up of old theories about the atom and the extension of our knowledge of atomic structure and atomic behavior. I shall try to give you a picture of what these developments have been and what is our present point of view regarding atoms, their structure and their relations to other atoms and to the phenomenon of radiation. Let me now run over rapidly a list of ten discoveries which I will call the ten most important advances of the last twenty years.

The first discovery on my list is the recent verification of the adumbrations of the Greeks regarding the atomic and the kinetic theories—the proof that, as Democritus had imagined 500 B. C., this world does indeed consist, in every part of it, of matter which is in violent motion.

Up to within ten years there were not a few distinguished scientists who withheld their allegiance even from these atomic and kinetic theories of matter. The most illustrious of them was Professor Wilhelm Ostwald, who at the world's scientific congress in 1902 publicly maintained that the facts of observation could just as well be explained without as with an atomic theory, but in the preface to a new edition of his "Outlines of Chemistry" he now says frankly:

> I am convinced that we have recently become possessed of experimental evidence of the discrete or grained nature of matter for which the atomic hypothesis sought in vain for hundreds and thousands of years. The isolation and counting of gaseous ions on the one hand . . . and on the other the agreement of the Brownian movements with the kinetic hypothesis . . . justify the most cautious scientist in now speaking of the experimental proof of the atomic theory of matter. The atomic hypothesis is thus raised to the position of scientifically well-founded theory.

I think you all know what the Brownian movements are but I wish especially to call attention to the fact that this advance was made not by a practical man, but by mathematical physicists; men who had the training, the penetration and the capacity to analyze phenomena and to develop necessary quantitative relationships between them. It is to Einstein of recent fame, to Smoluchowsky, a Pole, and to Sutherland of New Zealand to whom the credit for this advance is about equally due. The results consist in predicting, from the assumption that every particle suspended in a liquid or a gas, no matter what its

size, is endowed with exactly the same energy of random agitation, how far a given particle that you can see in an ultra microscope will drift in a given time, and our own experiments have checked this prediction to within one-half per cent. It is that sort of evidence that has convinced Ostwald of the correctness of the kinetic and the atomic theories.

The second advance is the proof of the divisibility of the atom, a proof which grew out of the discovery of roentgen rays. Let me tell you how. If you have two plates with an electric field between them, and nothing else but a monatomic gas like helium, it is found that when the field is thrown on, the helium is perfectly stagnant; but when a beam of roentgen rays is shot between the plates some of the molecules become electrically charged and begin to jump, a part of them toward the upper plate and a part toward the lower plate, where their presence can be detected by an electrical measuring instrument. What does that show? It shows that the thing which we call an atom has electrical charges as its constituents; and the history of the last twenty years in physics has consisted pretty largely in determining what are the properties of these electrical constituents.

The third discovery shows us something about what the atoms are doing. It came just a little after the discovery of roentgen rays. And here we found matter doing things we had never dreamed it could possibly do, namely, shooting off from itself chunks of matter, some of them charged positively and some negatively, with perfectly stupendous speeds, the negatives with a speed which may approach close to the velocity of light, 186,000 miles per second, and the positives with a speed of one-tenth of that, or 18,000 miles. The fact that such speeds could be imparted to projectiles of any kind was undreamed of twenty years ago. Such was the discovery of radioactivity.

The fourth discovery that I wish to mention is the discovery of the atomicity of electricity, the proof that the thing we call electricity is built up out of a definite number of specks of electricity, all exactly alike, and that what we call an electrical current consists simply in the journey along the conductor of these electrical specks, which we may call with perfect justice definite material bodies. Now, I can give you in just a word the proof of that statement. There are half a dozen ways in which it could be approached. I will mention the one with which I am most familiar, because it is the particular proof which we worked out at our laboratory.

We took round, brass plates with a field of 10,000 volts between them, with a little hole in the top plate, and we blew an oil spray above the top plate so as to get an electrically charged body just as small as we could, for we expected that the frictional process involved in blowing the spray would charge the drops, which it was found to do. We let one of those drops come into the space between the plates and then moved it up and down by an electrical field, throwing on the field as it came close to the bottom plate, and throwing it off as it approached the upper one, and so we kept that oil drop going up and down between the plates, in the hope that it would capture some of the ions which we knew existed in the air, put there by radium or other agencies. The drop met our fullest expectations as a police officer, capturing ions frequently and signaling the fact of each capture to the observer by the change in its speed in the field. For the oil drop is an electrically charged body, and in a given field it moves with a definite speed. If however it captures an ion, its charge increases or decreases, and hence its speed increases or decreases. If the charges or ions are all alike, then we can only get one particular change in speed. If the charge that is already upon it, put there by the frictional process, is built up out of these same units, then the total speed which the field will impart must be an exact multiple of the change in speed which the capture of an ion produces. In other words, if electricity is atomic in structure, you cannot get in a given field anything except a definite number speeds, which will make an arithmetical series, that is, will come up by steps, one, two, three, etc. That is exactly what we found. We have experimented with thousands of drops and scores of different substances, and they always work exactly that way. Both positively and negatively charged drops are found to act in quite the same way, showing that both positive and negative electrical charges are built up of specks of electricity. Further we can count the number of those specks, which we will call electrons, on a given drop, with the same certainty with which you can count the number of fingers that are before you now. And again since Rowland showed that an electrical current is nothing but a charge in motion, you have here the proof that the electrical current that goes through these lamps, for example, is nothing except the motion of a certain number of electrical specks through or over the filament of the lamp. Add to that J. J. Thomson's discovery made in 1881, that an electrical charge possesses inertia, the only distinguishing property

of matter, and you have made it perfectly legitimate to say that an electrical current in a wire is a definite, material, granular something which is moving along that wire.

The fifth great discovery of modern physics is the bringing forward of evidence for the electrical origin of mass. I have just said that electricity is material. Can we turn it around, and say that all matter is electrical in origin? The last is not exactly the same as the first, and it needs evidence. When we have proved that an electrical charge possesses inertia or mass we have not shown that there is no inertia in matter which is not electrical in its origin. Now we have a certain amount of evidence on this point and I wish to state what that evidence is. We can measure the inertia of the negative electron and it is found to be $1/845$ of the inertia of a hydrogen atom, but the positive electron is never found with an inertia less than the inertia of a hydrogen atom. Let us consider the inertia of the negative. So long as it is moving slowly compared with the speed of light its inertia remains constant because the shape of its electromagnetic field is not appreciably distorted by its motion. But as soon as you imagine it to be moving with a speed which is close to the speed of light, that is with a speed which is nearly as great as the speed with which its own electromagnetic field can travel forward, then further change in speed will distort the field and hence change the inertia. In other words, the inertia of a charge ought to be a function of speed only when the speed approaches the speed of light. As a matter of fact, when it is from 0.1 up to 0.9 of the speed of light, you can compute just how it ought to vary. Now, by some happy chance the physicist has found negative electrons, namely, those shot off by radium, which are going with these speeds, and hence it is possible to test our theory for these particles and see whether the rate of change of their inertia with the speed checks with the theoretical value. It is found that there is such a check. This means that there isn't any inertia in those particles which does not obey the electromagnetic laws. Therefore, we have good reason for assuming that the negative electron is nothing but a disembodied electrical charge, and that its inertia is wholly of electrical origin.

Now, with respect to the positive electron, we haven't that evidence as yet, but it is obviously in the interest of simplicity to assume one kind of inertia rather than two. Further, we have a little bit of evidence of this kind, and I wish to mention what it is, because that

will furnish an introduction to my sixth important modern discovery. We have good reason to think, at any rate, that there is only one positive electron in the hydrogen atom, but that the mass, or inertia, of that positive is almost the mass of the hydrogen atom—at any rate, we never find it any less. If this inertia is all electrical then we know from theory that the charge must be more condensed in the positive than in the negative; consequently, if we are going to make the observed inertia of the hydrogen nucleus all electrical, it must be even a more dense charge, that is a smaller body, than is the negative charge. So, we first get the picture by that kind of a theory of an atom which has an extraordinarily minute single positive nucleus, and negative electrons around the outside. We first got this picture by that kind of theory but we do not depend on that theory now, because we know that the conclusion is correct. We know that the atom does consist of a body with a positive nucleus which is extraordinarily minute, and we can tell just how large it is, if we define the nucleus as the part of the atom that is impenetrable to the alpha rays of radium.

This brings me to the sixth of our discoveries, namely, the discovery of the nucleus atom. Let me give you just a brief statement of how we know that the atom is somewhat like a miniature solar system, with an extraordinarily minute nucleus, the size of the nucleus never being more than 1/100,000 part of the diameter of the atom, with a certain number of subsidiary bodies—negative electrons—which we should liken to the planets, somewhere around the outside. How do we know that is the case? We have this direct evidence. In the phenomenon of radioactivity nature takes a helium atom which is going with a speed of 18,000 miles per second, and nature shoots that atom right through a glass wall without leaving any hole behind, and without in any way interfering with the structure of the molecules of the glass. I have photographs that make the thing so clear that the wayfaring man can see it. This obviously means that the positive nucleus itself must be extraordinarily minute. Indeed the fact that the negative electron actually shoots through those hundreds of thousands of atoms without ever going near enough to any constituent of those atoms to knock any one of them out, and the fact that the positive nucleus of helium, namely, the alpha particle, shoots through even more molecules without being deflected at all from its course, causes one to wonder whether there was anything at all that is

impenetrable in the atom. Why do we say there is a nucleus there? Because direct experiment says there is. There is a certain portion of the atom which the alpha particle itself cannot penetrate. If the impact is head on, the alpha particle goes right up to the atom and then it backs straight back again. It is only rarely that this kind of a rebound happens, but Rutherford and Geiger and Marsden counted the percentage of alpha particles which goes straight on, and the percentage which comes back, and in that manner, by perfectly simple algebraic analysis that any one of you can understand, without any assumption at all except the law of inverse squares, which can hardly be called an assumption, at least so far as the attraction between the positive nucleus and the negative electron is concerned, we find how big that nucleus is. By the size of the nucleus I mean the size of that portion of the atom which is impenetrable to the alpha particles. It comes out something like 10^{-13} centimeters. The diameter of the atom is 10^{-8}. Furthermore, by counting how the deflections of the alpha particles are distributed around this sphere, which we can do directly with the aid of zinc sulphide spread over the inside of the sphere, we can obtain the number of alpha particles deflected through any given angle, and then with a little analysis of unquestionable correctness, we find how many free unit charges positive electrons there are in this exceedingly small nucleus, and it comes out approximately one half of the atomic weight.

Now, I come to another extraordinary discovery which did not merely tell us approximately how many electrons there are in the nucleus but it told us exactly how many there are, and the result checked too with the number obtained by the foregoing approximate method. This brings me to the recent discoveries in the field of roentgen rays, and I will call the seventh of the modern advances the discovery of the nature of roentgen rays, which was virtually made by Barkla in 1904. For Barkla and others had proved that there are two types of roentgen rays, first roentgen rays which consist of simple ether pulses pushed off from an electron when it changes its speed; and second so-called characteristic roentgen rays which are formed thus: When the electrons bump into a target they set something in the target into vibration, and this something sends off perfectly definite characteristic roentgen rays, which are like monochromatic light. So, we have two types of roentgen rays; pulse roentgen rays,

like white light, and monochromatic roentgen rays, like monochromatic light, such as mercury gives rise to. That is the seventh of our great modern discoveries and it must be credited chiefly to Barkla.

The eighth I will call the discovery of crystal structure by the study of roentgen rays, which is due to Laue in Munich, and Bragg, in England. The method is simply this: In the Ryerson Laboratory we analyze light by a grating which consists of a series of equally spaced lines on a reflecting or transmitting surface. With such a device we can split light up into a spectrum but we cannot thus split it up unless the width of the grating space is comparable with the wave length of the light. In the case of roentgen rays, we had no knowledge of gratings whose grating spaces were as small as the wave length of roentgen rays, in fact such gratings were unknown until Laue had the bright idea of using the regular arrangement of the atoms in a crystal for a grating to see whether that would do the work, and it did the work marvelously well. It was found that we could compute the grating space of certain crystals from the density and the atomic weight and then from the observed spectrum we could find the wave length of roentgen rays. When we know the wave length we can work backward and find the grating space for other crystals. We are now using this method for finding the positions and the arrangements of the atoms in crystalline bodies. Bragg in his book on roentgen rays and crystal structure has described this work very well. Thus a whole new field of experimentation has been opened up and is being pursued in a great many laboratories, and with particular success in some. There are almost unlimited possibilities for the physicist and the chemist in the discovery of the exact position of the atoms in any kind of crystal by this method.

The results of this discovery, as of most of the others which I have mentioned, are rather insignificant when compared with those of the ninth which I am going to mention, namely, the discovery of the relations between the elements, and the extension of our knowledge of the radiations emitted by different substances. This discovery was made by a young Englishman only 26 years old, Moseley. Moseley was killed at the age of 27, a year after he made his epoch-making discovery, and all the lives and all the interests of the eternally infamous men who made the war are not to be compared in value to the world with a hair of Moseley's head. Yet he had to be sacrificed to save a threatened civilization—a double honor to Moseley.

His discovery was this: He was analyzing the characteristic roentgen rays which are given off when any substance is bombarded with cathode rays. The experiment was in my judgment as brilliantly conceived, as carefully and skilfully carried out, and as illuminating in its results, as any which has been done in the last fifty years. He found that the atoms of all the different substances emit radiations or groups of radiations which are extraordinarily similar, but that these radiations differ as we go from substance to substance in their wave lengths. The whole discovery can be stated in this fashion: If you take the highest frequency emitted by a given atom, and if you lay down on a table a length which is equal to the square root of this frequency, and if on top of that you lay down the square root of the frequency of the atom which has the next lower frequency, and if you continue to lay down, with one group of ends together, the measured square root frequencies of all the elements that you can study, what have you? You have a flight of stairs, with perfectly definite equal treads; that is, the frequencies change by definite steps as you go from element to element. And there are only four vacant treads between the lightest element that Moseley could study, aluminum, and the heaviest one, lead, thus indicating that there are only four elements in this range which we have not already found. An extremely interesting question is, What is the greatest common divisor of this series of steps, that is, what is the top step? There are two ways to get it. One is by filling all the spaces up to aluminum with known elements in the order of their weights—we cannot investigate the lighter ones by the roentgen-ray method because their frequencies are too low; at least, we have not yet found how to investigate them. Now there are just twelve elements below aluminum, so we may put them all in, starting with hydrogen. That would make hydrogen correspond to the top step. The second way is to find arithmetically the greatest common divisor of the square root frequencies. This gives us a frequency which is within a few per cent of the highest frequency which hydrogen can produce, according to Lyman's measurements in the ultraviolet region of optical radiations. This indicates again that hydrogen is the element corresponding to the first step. All of this seems to mean three things: first, that the roentgen rays of hydrogen are just its ordinary visible radiations; second, that Moseley opened up a whole new field of radiation, beginning with the radiations of hydrogen, and extending up to a frequency $(92)^2$ or 8464 times as

high as that given by hydrogen. I have squared 92 because 92 is the number of the step corresponding to uranium, the heaviest known element, and the one having the highest frequency in its characteristic roentgen rays. Moseley's discovery means in the third place, almost certainly, that the elements are built up one from another by successively adding the nucleus of the hydrogen atom. The probable reason for the change in frequency as the nucleus takes on a stronger and stronger charge is that the electron sending off say the highest characteristic frequency is in a stronger electrical field in the helium atom, for example, than in the hydrogen atom, and so as the charge on the nucleus goes up by successive steps in going from element to element frequencies go up by corresponding steps.

We may then picture with considerable confidence this whole physical world as built up out of one positive and one negative electron. The positive electron is the nucleus of the hydrogen atom. It is very minute in comparison with the negative, but much more massive; when two free positive electrons are tied together we have the helium atom. We don't know why these positives cling together. We can assume, as an hypothesis, that there are four positives in helium which are held together by two negatives, thus leaving but two free positions as experiment indicates in the case. The assumption here is that in the nucleus one negative is capable of holding two positives. This assumption would make the nucleus of any atom contain a number of negatives equal to the atomic number and a number of positives equal to twice the atomic number. So much for a brief and incomplete sketch of Moseley's contribution to modern physics.

The last of the great discoveries of modern physics is one that I will just touch on. It is the discovery of quantum relations in photoelectricity, in roentgen rays, and in optical spectra; but here I am coming to a field which we do not know much about, which we do not yet understand, and my main motive in introducing it is to convince you that the physicist, in spite of all he knows, or thinks he knows, is a fairly modest fellow, because there are some things he knows he does not know, and one at present is the nature of radiation. However, we know some things about it that are new. For example, it is an extraordinarily interesting fact that when light of the roentgen-ray type, or indeed, light of any frequency falls on say a lithium or sodium surface, or on almost any surface, it has the property in some way of taking hold of a negative electron in the atoms of that surface

and of hurling that electron out with a perfectly definite speed, which we can measure, and which we find to be exactly proportional to the frequency of the light. That is an extraordinary phenomenon, and it is one that we explain on a kind of quantum theory which I will not attempt to go into here, because of the fact that we have not yet worked it out fully, so that I cannot tell you anything definite about it; but at any rate, the quantum constant comes out of the photo-electric effect, as shown in my own work, out of roentgen-ray work as discovered by Duane and Hunt at Harvard, and out of spectroscope work, as shown by Bohr in the beautiful theory of the atom which he has developed within the last three or four years.

I think I have brought you in this brief survey to the outmost boundaries of our present knowledge. Bring me back ten years from now, and we will know more about these quantum theories; but for the present I will stop, and close this hasty survey of the problems and successes of modern physics.

DISCUSSION

WILLIAM D. HARKINS: I wish to call your attention to two interesting facts that have been called to my mind by Professor Millikan's paper. The first of these is that of all of the ten great discoveries in physical science of which he spoke, not one was made in America, although it should not be forgotten that one of the most important of modern physical theories, that of relativity, is based on the experimental results obtained in this country by Professor Michelson; and the second is that the twentieth century of science, as he described it, covers a considerable part of the last decade of the nineteenth century. Indeed, in this decade, a new era in physical science began, for in these few years the electron was discovered, and isolated as a negative corpuscle; and roentgen rays, radioactivity, and Hertz waves were all found experimentally in the twelve years before the beginning of the present century. In the discovery and isolation of the electron the work of Crookes and J. J. Thomson, together with that of Weichert, plays the most important part, and that of C. T. R. Wilson and of H. A. Wilson is of great value.

In connection with the recent great developments in the knowledge of the structure of the atoms, the researches of J. J. Thomson and of Rutherford are the most fundamental. It is to the latter that we owe the theory that the heavier atoms are disintegrating and giving off the nuclei of helium atoms (alpha particles with a double positive charge) and negative electrons. He is also the author of what is termed the nuclear theory of the atom, which is that the atom is in a certain sense an extremely small scale solar system in which the sun is replaced by the nucleus of the atom. This nucleus carries a positive charge of electricity, and contains practically all of the mass of the atom. In the minute solar system the planets are negative electrons.

What we call a chemical element is so named according to the number of the planets in such a solar system, that is, according to the number of these planetary electrons. Thus, any electrically neutral atom in which there is only

one planetary electron is called a hydrogen atom. If there are six such electrons, it is called a carbon atom; if eight, an oxygen atom; if twenty-six, an atom of iron; if eighty-two, an atom of lead; if eighty-eight, an atom of radium, and if ninety-two, an atom of uranium. No atomic solar system thus far considered has more than 92 planets, so there are only 92 chemical elements, of which 86 have been discovered already. It is, of course, possible that future discoveries will reveal atoms with more than 92 planetary electrons.

It is of interest to consider that all of the great differences between oxygen and nitrogen, as they react in the animal body, are due to the presence of 6 planetary electrons in each atom of the former, and 7 in each of the latter; and that the great difference between hydrogen, which is present in all organic substances, and helium, which does not unite chemically with anything else, is due to the presence of 1 negative planetary electron in each atom of hydrogen, and of 2 in each atom of helium. It is found that those planetary electrons which are nearest the outside of the atom have much more to do with its chemical and physical properties, than those which are closer to the nucleus. Thus these properties seem to depend largely on how well the outer part of the atom is filled with electrons. It may be considered that the planetary electrons in an atom are arranged around the nucleus in a series of concentric spherical shells, as has been done by Lewis and Langmuir. In the first shell next outside the nucleus there are 2 planetary electrons; in the second, 8; in the third, 8; in the fourth, 18; in the fifth, 18; and in the sixth, 32. If only two shells of planetary electrons are present, the atom may be said to be complete if it contains 8 electrons in the *outer* shell, as is the case with neon, that is, the outer shell is *completely full* of negative electrons. Such a full shell is extremely stable, and will neither take up nor give off any electrons, so that the atom is incapable of undergoing chemical changes. If, however, there are only 7 negative electrons in the outer shell of the electrically neutral atom, this shell tends to take up an extra negative electron in order to complete the shell and give it 8 electrons. This taking up of an extra negative electron gives the atom a single negative charge in excess, and we say that the atom has been converted into a negative ion with one charge. Atoms of both fluorine and chlorine contain 7 planetary electrons in their outer shell, and both substances readily give negative ions. If, however, as is the case with a sodium atom (with 11 planetary electrons in all), there is only one negative electron in the outer shell, this is held loosely and tends to escape from the neutral atom, leaving a positively charged ion which has 8 planetary electrons in its outer shell. Thus, what we call negative elements are those which contain atoms in which the outer shell of electrons is nearly full, and therefore tends to complete itself; and what we call positive elements are those in which the outer shell contains so few electrons that it tends to lose the few it has.

Nothing has been said thus far as to how the planetary electrons are held around the nucleus. It is considered that the planets are held in their positions in the solar system by what is termed the gravitational attraction between the planets and the sun. In the atom the electrons seem to be held in place largely by an electrical attraction between the negatively charged planetary electrons and the positively charged nucleus. In any neutral atom the number of planetary electrons is equal to the charge on the nucleus, when the latter is expressed in terms of the net number of positive electronic charges which

it carries. Thus the positive charge on the nucleus of a chlorine atom is 17, and the chlorine atom has, therefore, 17 planetary negative electrons outside the nucleus.

It is easy to cause the planetary electrons in an atom to escape, as, for example, by simply allowing ultraviolet light to fall on the surface of a body; but the nucleus of the atom is exceedingly stable and can be broken up only by the use of energy in a high concentration. We all know that in experiments on an ordinary scale positively charged particles if brought close together exhibit a repulsion. It therefore seems somewhat peculiar to find that the positively charged nucleus, the parts of which, from this standpoint, should repel each other, has actually such an extremely high order of stability.

There is considerable evidence, which cannot be considered here, that the nuclei of all atoms heavier than that of hydrogen, are built up from positive electrons, which are the nuclei of hydrogen atoms, and that these positive electrons are bound together by negative electrons which may be called "binding electrons." These binding electrons should not be confused with the planetary electrons in the outer part of the atom, though the same negative electron might be a binding electron at one time and a cementing electron at another. While the atom is very small—of the order of 10^{-8} cm. (one ten millionth of a millimeter) in diameter—the nucleus has a diameter not much greater than that of a single negative electron, or its diameter is from a ten-thousandth to a hundred-thousandth that of the atom. The extremely high density of material in an atom nucleus may be illustrated by the statement that if one cubic centimeter of material could be made up of the nuclei of atoms tightly packed, its weight would be of the order of ten million tons, in case the dimensions of the nucleus are of the order calculated by Rutherford.

The lightest of all atoms, that of hydrogen, has a weight of 1.0077 (on the basis of oxygen as 16); while that of helium has a weight of 4; that of carbon, 12; that of fluorine, 19; that of sodium, 23, etc. It is of interest to note that these are all whole numbers with the exception of the weight of the hydrogen atom alone. We are thus forced to the conclusion that whenever a helium atom (or an atom of carbon, oxygen, fluorine, sodium, or any other complex atom) is built up from hydrogen atoms, there must be a loss of weight, and presumably of mass, in the process. This loss of mass is evidently equal to 0.76% of the hydrogen which is used up. In what form is this mass lost? If we adopt the modern point of view that mass and energy are the same, though measured in different units, an explanation of this loss is not difficult to find. Let us assume that the nucleus of a helium atom, which carries a positive charge of 2, is made up from 4 positive electrons and 2 negative electrons (4+ plus 2— gives 2+). Then it may be assumed that there would be an attraction between the positive and the negative electrons, but that the positive electrons would repel each other, and the negative electrons would also repel each other. The nucleus would therefore arrange itself so that the electrons of unlike sign would be close together, while those of like sign would be as far apart as possible. This is represented by the model presented in fig. 1, in which the large disks represent negative, and the small spheres, positive electrons. The electrons need not have the shape given in the model in order to have the arrangement represented.

If we suppose that a positive and a negative electron are far apart and are pulled together by the attractive forces between them, work being done, then it is apparent that the energy of the system will decrease; and this energy loss represents, according to the theory, a loss of mass, which presumably

escapes as some form of radiation. Thus there seems to be a loss of mass of 0.76%, which may be called the packing effect, whenever a complex atom is built up from positive and negative electrons, that is, from hydrogen atoms, since the hydrogen atom consists of one positive and one negative electron.

Let us now consider the stability of atoms, which means the stability of their nuclei, since if some of the negative planetary atoms escape from the outer part of the atom we say the atom is ionized, while if either negative or positive electrons escape from the nucleus, we say the atom has disintegrated. This method of speaking has been adopted because when the atom loses planetary negative electrons it easily picks them up again and returns to the state of the original atom, that is, the change is reversible, while particles lost from the nucleus have not in any case, so far as we now know, returned to its structure again. If a whole atom is to be built, containing, say 20 positive electrons, it will contain 20 negative electrons. On the other hand, in the building up of the nucleus of this atom, all of the 20 positive electrons are included, but only half this number, or 10 negative electrons, are used. This is the general rule for light nuclei—that one negative electron will bind two positive electrons, but in the heavy atoms, when the positive charge on the nucleus becomes high, the nucleus is extremely unstable unless the relative number of negative electrons is increased.

If N is taken to represent the total number of negative electrons in the nucleus, and P, that of the positive electrons, then for any value of P-N which is the net positive charge on the nucleus, there is a certain value of the ratio N/P which gives the most stable atom. As has been stated, this value is 0.5 or ½ for the light nuclei, that is, when the positive nuclear charge is small. The most abundant atoms in the earth's crust and in meteorites are those of oxygen, silicon, magnesium, calcium, and iron; and all of these, with the exception of iron, in which the value is only slightly higher, have values of N/P exactly equal to ½. In the nucleus of the uranium atom, which has the highest positive charge and the mass of all of the atoms, this ratio rises as high as 0.614. When in any nucleus the ratio N/P is higher than corresponds to a stable condition, that is, when the relative number of negative electrons is high, there is in general a tendency for the nucleus to give off negative electrons (beta particles), while if N/P is abnormally low (that is, if P/N and therefore the number of positive electrons is relatively high) there is a tendency for the atom to disintegrate by giving off positively charged, or alpha, particles.

The characteristic of the atoms of any one element, such as iron, is not that its atoms have a certain atomic weight, but that the value of P-N (which may be designated by n) or the positive nuclear charge, is the same in all of them. Thus an atom might have a nucleus containing 56 positive electrons (which would give it an atomic weight of 56) and 30 negative electrons. Since $56 - 30$ is 26, and 26 is the nuclear charge characteristic of iron, this would be an atom of iron. However, another nucleus might contain 52 positive electrons, and therefore have an atomic weight of 52, and if it should happen to contain 26 negative electrons, it would also be an iron atom since as $52 - 26$ is 26, the nuclear charge is the same as before. Atoms which have the same value of P-N or n, have also the same number of planetary electrons and the same chemical and physical properties, and are called isotopes.

Thus the element chlorine, which was formerly supposed to have an atomic weight equal to 35.46, is now found to consist of a mixture of two isotopes which have atomic weights 35 and 37, with probably a small percentage of

still another isotope of atomic weight 39. Although the nucleus of the first of these isotopes contains 35 positive and 18 negative electrons, the second contains 37 positive and 20 negative, and the third contains 39 positive and 22 negative electrons; all of these are now said to belong to one element, since $35-18=37-20=39-22=17$, which is the nuclear charge of chlorine.

I am trying to call to your attention that what we have called, and still call, an element is often a mixture of two or more different substances, which may be separated in the laboratory, and which are therefore much more truly elements than the 92 so-called chemical elements. The first separation of an element into such parts, which was carried out experimentally, was made by Mr. C. E. Broeker and myself at the University of Chicago, and was carried out with the element chlorine. The atomic weights of the different kinds of chlorine were determined, without separating them, by Aston at Cambridge University. It should be said that the existence of such isotopes was first recognized in radioactive elements by Soddy, Fajans, and others.

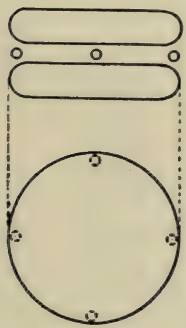

Fig. 1.—Arrangement of electrons in nucleus of helium atom.

It is now quite evident that from the standpoint of the structure of the nuclei of atoms there are at least three or four hundred elements, or what are more technically known as species of atoms; and that the atomic weight of all these pure species is always nearly a whole number on the basis of oxygen as 16 if the nucleus is complex, but is not a whole number for hydrogen in which the nucleus consists of one positive electron.

According to the theory developed by Harkins and Wilson in 1914, the most abundant constituent of all complex nuclei is the helium nucleus, with a mass of 4; there is a less abundant constituent with a mass of 3, and another with a mass of 2. All of these groups are built up of positive electrons (hydrogen nuclei) and negative electrons. All of the most abundant atoms—oxygen, silicon, iron, magnesium, calcium, sulphur, and nickel—seem to have nuclei which are built either from helium nuclei alone or with these, together with 2 negative cementing electrons in the cases of iron and nickel. The above 7 atoms make up 90% or more of all known material.

The following factors seem to give stability to an atom: (1) a low nuclear charge, (2) a normal value of N/P, and (3) the presence of an even number of negative electrons in the nucleus. The effect of factor 3 is seen in the fact that not more than one atom nucleus in 3,000 in known material contains an odd number of negative electrons. A fourth factor of importance

is that atoms which contain an even number of positive electrons are in general more stable than those which contain an odd number. Since both N and P in an atom nucleus are both usually even numbers, it is evident that P-N is also even; that is, the nuclear charge is usually an even number. The numerical value of the nuclear charge is called the atomic number. Figure 2 in which the abundance of the elements is plotted on the vertical, and the atomic number on the horizontal axis, shows clearly that the elements of even atomic number are by far the more abundant, since every even numbered element is represented by a peak and every odd numbered element by a trough.

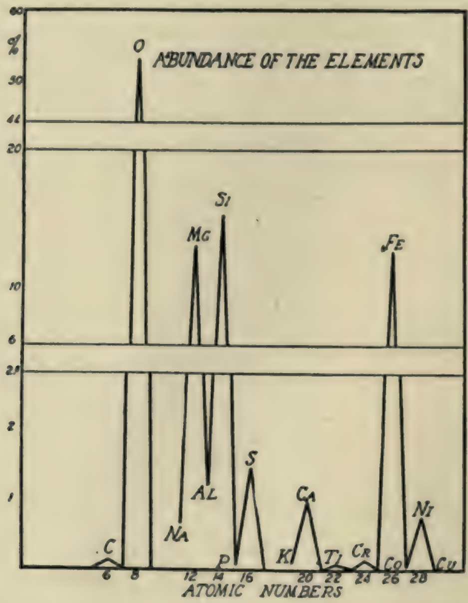

Fig. 2.—Atomic percentage abundance of the atoms in 350 stone to 10 iron meteorites, which is in the ratio of known falls. This is supposed to represent the average composition of materials as perfectly as can now be determined.

C. S. BACON: I would like to ask what has become of the ether. Has it disappeared and its place been taken by something else?

R. A. MILLIKAN, closing: I should be glad to answer, from my point of view, Dr. Bacon's question on the ether. Light and heat travel from sun to earth in some way or other. There are two hypotheses as to how they get there. One is the Newton hypothesis, the corpuscular theory, that light consists of minute particles of matter given out from a luminous body. If that is correct, any speed with which light travels must be a summation of the speed of ejection and the speed of the body which is emitting the light. The other hypothesis is that light is not corpuscular, but is a wave-motion which is propagated through space with a speed which is determined by the properties of the space and by nothing else. Of these two hypotheses, the first is abso-

lutely dead. The corpuscle theory has long been exploded and will never be revived, because we have definite experimental evidence that the speed of light bears no relation to the speed of the body emitting the light. That leaves only the second hypothesis, which is the one we have maintained for years, namely, that light and heat travel through interstellar space with a speed that has to do with the properties of the space itself. I do not care whether you call it space or ether. We have already called it ether and there is no particular sense in changing the name now. All this talk about the recent discoveries having made it necessary to modify our use of the term ether is pure folly from my point of view, because ether never had any properties except the property of transmitting electromagnetic disturbance. The whole controversy seems to me to be a quarrel over names rather than over ideas.

W. D. HARKINS: Do not some of the relativists at least indicate that light radiation consists of pulses?

R. A. MILLIKAN: What do you mean by a pulse?

W. D. HARKINS: They consider a pulse of radiated light as perhaps containing some material hurled from luminous bodies through space.

R. A. MILLIKAN: If I have a charged pithball and suddenly thrust it forward, a pulse certainly goes off through space just exactly as when I start or stop an electric current. There is no objection to the use of the term pulse. I used it in the foregoing talk. I do not think there would be any controversy on that point.

It is true, as I think you indicated, that some of the relativists seem to think that the recent discoveries in the field of physics are disastrous to the existence of ether. But from my point of view the relative theory has nothing to do with the ether. I think that is Professor Lunn's view, too. The physicists of the last century went farther than they were justified in doing in ascribing mechanical properties to the ether. All we know about ether is that there is something that transmits heat and light. We have no reason for talking about other properties. But we are going farther than our experiments entitle us to go.

SOME INFLUENCES OF FRENCH SCIENCE ON MEDICINE

THE PASTEUR LECTURE

GRAHAM LUSK

October 29, 1920

In a beautiful apartment in the Latin Quarter of Paris there lives today an elderly gentleman, the grandnephew of Lavoisier, Monsieur de Chazelles. On one wall of a salon in the apartment hangs a large painting by David of Lavoisier and his wife, both represented life size. Lavoisier, seated at his desk, has just stopped writing to turn his face toward his wife and she stands with her arm on his shoulder. Chemical apparatus are on the table and lie on the floor.

On another wall a fine portrait represents an ancestor as he appeared at the court of Louis XIV. And in the same room one finds a portrait of Benjamin Franklin which the latter sent to Lavoisier with a letter to the effect that it was one of two painted by a Frenchman then in America and that he considered them the best portraits ever made of him.

In the adjoining study of M. de Chazelles hang two drawings by Madame Lavoisier which were executed after the death of Lavoisier and retouched by David, who was Madame Lavoisier's master. These drawings represent her recollection of the first respiration experiments ever made on man. And in the desk in the same room are letters and papers of Franklin which have never been published, and which from his day to the present have been in the possession of the descendants of Lavoisier. There is a letter which contains drawings of a kite suggested to Franklin by a sailor, and a description of how he would improve it; there is an account, illustrated with drawings, of a small boat which could be propelled by forcing water from the stern by means of a piston; and there is a discussion of a suggestion that sugar was stained red with human blood, but Franklin arrives at the conclusion that when one contemplates the wars waged for the possession of the West Indies and the loss of negro slave life associated with the culture of the sugar cane, all the sugar consumed in Europe is to be considered as soaked crimson with blood.

I owe the privilege of seeing these things to my friend, Professor Jean le Goff of Paris, to whom I also owe the possession of the most important French classics on metabolism, including the sumptuous "Oeuvres de Lavoisier" published by the French government during the reign of Napoleon III. For all these treasures I am deeply grateful to him.

Lavoisier and Franklin were intimate friends, living near each other in Paris, and Franklin dined frequently with the great French chemist and his wife. In a letter written to Franklin on Feb. 5, 1790, during the early days of the French Revolution, Lavoisier says:

> After having recited what has transpired in chemistry, it is well to speak of our political revolution. We regard it as accomplished, well accomplished and beyond recall. There still exists, however, an aristocratic party which is making vain efforts but is evidently feeble. . . . We greatly regret at this moment your absence from France. You could be our guide and mark the limits beyond which we ought not to pass.

The family of Antoine Laurent Lavoisier traced its ancestry back seven generations to Antoine Lavoisier who was a post-boy in the stables of the king, and who died in 1620. Successive generations raised the position of the family name to ever higher levels until it was said of the great Lavoisier that it would require perhaps a hundred years for the appearance of his equal. Native intelligence, a fine education, great wealth, combined with the environment of the searchingly critical atmosphere of the Paris of his day, allowed of the vivid inspiration which filled his life.

Perhaps it may be fruitful to inquire into the state of chemical physiology preceding the time of Lavosier. Robert Boyle in 1660 showed that the flame of a candle or the life of an animal was extinguished after placing them in an air pump. A contemporary of Boyle, John Mayow of London, believed that air contained "nitro-aerial particles" which supported combustion and animal life. He also showed that such particles added to the weight of antimony when that metal is burned by the sun's rays and that the nitro-aerial particles contained in saltpeter, which are able to burn sulphur, are the same particles as those found in air. This was the first discovery of oxygen but it was entirely forgotten and later, when Lavoisier asked Magellan to seek for a copy of Mayow's publication, it was not to be found in any of the libraries of London.[1]

[1] Grimaux: Lavoisier, 1896, p. 107.

The German chemist, Stahl, who in 1716 moved to Berlin as physician to the king of Prussia, was the originator of the phlogiston theory of combustion, which enthralled the minds of men for nearly a hundred years. According to this theory, all combustible substances contained phlogiston which passed from them when they were burned. What we now know as oxides of iron or lead were those metals which through burning had lost their phlogiston. Such substances, if calcined with carbon, a material supposed to be rich in phlogiston, absorbed phlogiston and became metals once more. This simple theory availed to explain all the phenomena of combustion, and it was generally accepted by the scientific world.

The great physiologist, Albrecht von Haller, who died in 1777, writing his "Elementa Physiologica" [2] in the middle of the eighteenth century, has this rather hazy conception of the process of respiration:

> The secondary uses of respiration are very numerous. It exhales copiously and removes from the blood something highly noxious; for by remaining in the air it will cause suffocation; and the breath of many people crowded in a close and small place impregnates the air with a suffocating quality. On the other hand, it absorbs from the air a thin vapor of which the use is not sufficiently known.

Benjamin Franklin in "Poor Richard," 1746, thus poetically popularizes the ideas of his time:

> "Like cats in air pumps to subsist we strive,
> On joys too thin to keep the soul alive."

It must be remembered that in those days many chemists still based their ideas on the assumption of the four elements of Empedocles, air, fire, earth and water; ideas which were to be overthrown when air was shown to be a mixture of gases and water a chemical compound of gases.

One of Lavoisier's close friends was Joseph Black, professor of chemistry at Edinburgh. Black, in 1754, had found that magnesium alba, when heated, lost half its weight and that it gave off a gas when treated with acids. The gas eliminated he called "fixed air." He also found the same "fixed air" produced in fermentation, in the combustion of carbon and in expired air. Black in these experiments discovered carbonic acid.

[2] First Lines of Physiology, Trans. of Third Latin edition by William Cullen, Edinburgh, 1801, p. 131.

Nitrogen was the next gas to be revealed. In 1772, Rutherford, a friend and colleague of Black, found that when a candle was burned in an enclosed vessel until it went out and the "fixed air" was then absorbed by alkali, there remained a large volume of air which extinguished life and flame in an instant. This irrespirable gas was subsequently called nitrogen.

A year before this Priestley, in 1771, introduced a growing sprig of mint into an atmosphere in which a candle had burned out and after a lapse of several days found that another candle burned in it perfectly. Evidently the burning candle filled the space with phlogiston; the growing plant absorbed the phlogiston and produced "dephlogisticated air." This could again receive phlogiston when the second candle burned.

Shortly after this discovery (1774) Priestley submitted red oxide of mercury to the heat of a burning glass and found that an air was evolved in which a candle burned very vigorously. Priestley assumed that this air was pure dephlogisticated air, while common air was only partly dephlogisticated.

Priestley explained the presence of Black's "fixed air" in the expired air thus: "It will follow that in the precipitation of lime by breathing into lime water the fixed air which incorporates with lime comes not from the lungs but from the common air, decomposed by the phlogiston exhaled from them." And Priestley, who was one of the discoverers of oxygen, was gathered to his fathers at Northumberland, Penn., in 1804, still believing the phlogiston theory of combustion.

Independent of Priestley and before him, Scheele, a Swedish apothecary and eminent chemist, discovered oxygen by decomposing dioxide of manganese and other substances. Scheele believed that the atmosphere was composed of "spoiled air" and "fire air." When a body burned in air it lost its phlogiston, which united with "fire air." Heat consisted of "fire air" united with phlogiston. It passed through glass. In this way a portion of air could pass through glass.[3]

In 1771, Scheele[4] found that when silver carbonate was heated in a retort "fixed air" was liberated, as well as "fire air," while a residue of metallic silver remained. In 1775, he placed silver carbonate in a small retort connected with a collapsed bladder and then heated the substance. Two airs were evolved, "fixed air," which he removed with lime water, and "free air," in which a flame burned brightly. In

[3] Scheele's Briefe, p. 79, a letter of November, 1775.

[4] Physische und chemische Werke, Berlin, 1793, 1, p. 90; Briefe pp. 80, 407 and 466.

the interim between these two experiments he wrote Lavoisier in Paris a letter [5] dated Sept. 30, 1774, asking him to use his powerful burning glass on silver carbonate, then to absorb the "fixed air" in lime water and to observe whether a candle would burn and an animal live in the remaining air, and he begged Lavoisier to inform him of the results.

Scheele [6] did another striking experiment. He placed two large bees together with a little honey in a small upper chamber of a glass apparatus which he had devised. This upper chamber was in communication with a glass cylinder. He filled the glass cylinder with "fire air" and immersed its lower end in lime water. The volume of the air within the receptacle diminished day by day and the lime water which absorbed the carbonic acid rose in the tube. After eight days the bees were both dead and the lime water almost completely filled the space.

It is evident that Scheele had introduced bees into pure or nearly pure oxygen gas and that the carbon-dioxide which they produced had been completely absorbed by the lime water.

Scheele made no direct comment on this truly beautiful experiment, but in the general criticism of several experiments one may read the following hazy generalization:

> Why do not the blood and lungs change "fire air" into "acid air"? I take the liberty to express my opinion concerning this, for what would such exacting experiments profit unless through them I had the hope to more nearly approach my ultimate aim, the truth. Phlogiston, which combines with most substances, causing them to become more fluid, more mobile and more elastic, must have the same influence upon the blood. The blood corpuscles must absorb it from the air through delicate openings in the lungs. Through this combination they are expanded and in consequence become more fluid. In some part of the circulation they must give off this absorbed phlogiston and consequently be able to again absorb this fine principle when they next reach the lungs. Whither the phlogiston goes during the circulation I will leave to others to find out. The affinity of blood for phlogiston can not be as great as in the instance of plants and insects which take it from the air and also the blood cannot convert it into "acid air," but it is changed into a kind of air which is midway between "fire air" and "acid air," it is "spoiled air." For it does not unite with lime water or water as does "fire air," though it extinguishes fire as does "acid air."

Scheele's "spoiled air" was nitrogen. The poor struggling apothecary, who had made so many careful and accurate experiments and

[5] Scheele's Briefe, p. 406.

[6] Ueber Luft und Feuer, 1777, in Physische und chemische Werke, Berlin, 1793, p. 209.

who was one of the greatest chemists of his time, was unable to interpret his results without adherence to the dominant fetish of phlogiston.

We have here the picture of two earnest men, Priestley and Scheele, both absorbingly interested in chemistry, both contributing important knowledge and ranking among the greatest scientists of their day, and yet neither had the philosophical acumen to understand the meaning of their experiments. Priestley was a dissenting clergyman earning his living by preaching, but in his old age his house was burned by loyalists, and he shortly afterward fled to America. Scheele, though honored by scientific men the world over, remained a poor apothecary to the end of his days. In the current parlance of today these two great contributors to human knowledge would undoubtedly have been known outside their own circles as "narrow minded scientists."

This, however, could never have been said of Lavoisier, who repeated and extended their experiments, overthrew the phlogiston theory and established modern chemistry.

Lavoisier was elected a member of the Académie des Sciences in 1768 at the age of 24. About the same time, desirous of promoting his personal fortune, he became associated with la ferme générale, through whose activities taxes were collected in France. Some of his fellow academicians looked askance at this undertaking, but the mathematician Fontaine is reported to have remarked, "Never mind, he will be able to give us better dinners." [7]

In the ferme générale the young man was the subordinate of one Paulze, a nephew of the then all powerful Terray, minister of state and controller of finance. At the age of 28 Lavoisier married the 14 year old daughter of Paulze. His own position and his marriage brought him great wealth but in no way diminished his tireless activity. He congratulated himself that his patronage of the instrument makers of Paris had rendered France independent of Great Britain in the manufacture of scientific instruments.

Lavoisier's first paper before the Académie was "On the Nature of Water and on Those Experiments which Pretend to Prove Its Transformation into Earth." In this experiment he hermetically sealed rain water in a flask and boiled it for 101 days. Mineral matter appeared in the flask but the whole did not change in weight, and the mineral

[7] Grimaux: Levoisier, 1896, p. 32.

material that appeared was shown to be derived from the disintegration of the flask itself, which lost in weight. Lavoisier used an extremely sensitive (trés-exacte) balance, made by the official who was charged with the weighing of gold.

Here we witness the overthrow of a dogma more than two thousand years old, accomplished by the introduction of the quantitative method into chemistry. One may recall the words of Lavoisier written in his "Elements of Chemistry." [8]

> As the usefulness and accuracy of chemistry depend entirely upon the determination of the weights of the ingredients and products both before and after experiments, too much precision cannot be employed in this part of the subject and for this purpose we must be provided with good instruments. . . . I have three sets (of balances) of different sizes made by M. Fontin with the utmost nicety; and excepting those made by Mr. Ramsden of London I do not think that any compare with them in precision and sensibility.

Lavoisier had a balance which could weigh 600 gm. within 5 mg. and another which was sensitive to within a tenth of a milligram, which were quite up to modern standards of accuracy. One may visit the Conservatoire des Arts et Métiers in Paris and see there a notable collection of Lavoisier's apparatus. One sees a gasometer for the accurate measurement of gases; there is the celebrated ice calorimeter of Lavoisier and La Place; there also are barometers of finest workmanship, set in mahogany supports decorated with gilded filagree work, reminding one of the choicest furniture. These treasures were placed in the cellar of the Conservatoire during the bombardment of Paris by the Germans during the late war.

Concerning the gasometers, Lavoisier [9] wrote:

> It becomes expensive because in many experiments, such as the formation of water and of nitric acid, it is absolutely necessary to employ two of the same machines. In the present advanced state of chemistry very expensive and complicated instruments are become indispensably necessary for ascertaining the analysis and synthesis of bodies with the requisite precision as to quantity and proportion.

It is strange that Lavoisier's insistence on the use of accurate, quantitative measurements, through the application of which nearly a hundred and fifty years ago he brought about the "Chemical Revolu-

[8] Elements of Chemistry, trans. by Robert Kerr, Philadelphia, 1799, p. 375.

[9] Elements of Chemistry, Philadelphia, 1799, p. 397.

tion," should appear as new truth when enunciated by some of our ultra modern scientists.

In the heart of France near Puy-du-Dome, at Château de la Carriére, now owned by Monsieur de Chazelles, there is a veritable museum of scientific apparatus which formerly belonged to Lavoisier.[10] There are several thermometers of great accuracy and a fine balance, and there are three large glass globes, one capable of holding 15 liters of air, another 12 liters and a third 7 liters; also many other treasures of great historic value. Lavoisier made his experiments before the days when rubber and cork reduced laboratory expenses. His glass tubes and receptacles were united with finely polished brass joints.

We may imagine this accomplished Frenchman at work in his laboratory, or in his library, or receiving information from visitors to the fashionable and brilliant capital of France. It is related [11] that Priestley dined with Lavoisier in Paris in October, 1774, and informed him concerning the production of "pure dephlogisticated air" from oxide of mercury, and we may also recall that Scheele, on September 30 of the same year, wrote to Lavoisier asking him to expose silver carbonate to the heat rays of a large burning glass and produce "fixed air" and "fire air" from them.

Ten days after his conversation with Priestley, and again during the month of the following March, Lavoisier went to Montigny to visit his friend Trudaine, who was the owner of an immense burning glass 42 inches in diameter which had cost 15,000 livres (about $3,000), and here he repeated Priestley's experiments. In the paper read before the Académie des Sciences at Easter, 1775,[12] Lavoisier stated that he took the red mercury calx and heated it with carbon and obtained "fixed air," and when he heated the same without carbon a gas was evolved in which a flame burned with the splendor of phosphorus in air, and that this gas was the "air eminently respirable." The loss in weight of the mercury calx was equal to the weight of the "air eminently respirable" given off. He concluded that "fixed air" was the result of the union of carbon with "air eminently respirable."

In a subsequent paper [13] he reported that it was this "air eminently respirable" which was absorbed by phosphorus and sulphur when they burn with the production of phosphoric and sulphuric acids.

[10] Truchot: Annales de Chimie et de Physic, 1879, 18, p. 289.
[11] Thorpe: Essays in Historical Chemistry, 1902, p. 160.
[12] Oeuvres de Lavoisier, Paris, 1862, 2, p. 122.
[13] Oeuvres de Lavoisier, Paris, 1862, 2, p. 139.

Having discovered these facts, Lavoisier proceeded to determine the effect of a sparrow on the content of air in a confined space. In a brief memoire,[14] published in 1777, he enunciated the principle that during respiration it was only "air eminently respirable" (oxygen) which disappeared from the atmosphere when an animal was put into a confined space and that this air was supplanted by expired "aeriform calcic acid" (carbon-dioxide); that when metals were calcined in air oxygen was absorbed until its supply was exhausted; that if after an animal had perished in a confined space the carbon-dioxide in the atmosphere was absorbed by alkali the "foul air" remaining was the same kind of air as that found after metals had been calcined in air in an enclosed space. All the former qualities of this air could be restored by adding to it "air eminently respirable."

Three years later than this Lavoisier and La Place [15] made another step in advance. They noticed that a guinea-pig produced 224 grains of carbonic acid in ten hours and that what would now be called the respiratory quotient was 0.84. Then they put a guinea-pig in their recently constructed ice calorimeter and found that the heat given off by the animal melted 13 ounces of ice in a period of 10 hours. Next they calculated that if carbon was oxidized so that 224 grains of carbonic acid were produced, 10.4 ounces of ice would have been melted. They realized that in the case of the guinea-pig allowances would have to be made (1) because the legs of the animal became chilled during the experiment; (2) because the water of respiration was added to that of the melted ice, and (3) because the influence of cold increased the heat production of the animal. But they nevertheless stated:

> Since we have found in the preceding experiments that the two qualities of heat obtained are nearly the same, we can conclude directly and without hypothesis that the conservation of animal heat in the animal body is due at least in greater part to the transformation of "air pur" (oxygen)) into "air fixé" (carbonic acid) during the process of respiration.

Here be it noted that Lavoisier refers to the conservation of animal heat more than fifty years before the general law of the conservation of energy was enunciated. He also observed that two sparrows produced about the same quantity of carbonic acid in the unit of time as did a guinea-pig.

[14] Lavoisier: La respiration des animaux, Mém. d l'Acad. d. sc., 1777, p. 185; Oeuvres de Lavoisier, Paris, 1862. 2, p. 174.

[15] Lavoisier and La Place: Mém. de l'Acad. d. Sc., 1780, p. 355; Oeuvres de Lavoisier, Paris, 1862, 2, p. 283.

About a year after these experiments (1781) Cavendish in England found that when two volumes of "inflammable air" (or hydrogen) and one volume of Priestley's "dephlogisticated air" were united by an electric spark, the airs disappeared and water resulted. Cavendish concluded that dephlogisticated air was water deprived of its phlogiston.

It is said that Lavoisier, hearing of these experiments from Blagden, secretary of the Royal Society of London, repeated them.[16] But the important point is that Lavoisier was the first really to understand the phenomenon. In a memoire presented to the Académie des Sciences in 1783,[17] he stated that water is merely a combination of "inflammable air" and oxygen and that any heat or light produced by their union is imponderable.

In the same year Lavoisier completely demolished the phlogiston hypothesis and concluded his memoire "Reflections upon Phlogiston" with the following words.[18]

> My object in preparing this memoire has been to record the new developments of the theory of combustion which I published in 1777, to show that the phlogiston of Stahl, which he gratuitously supposed existed in metals, sulphur, phosphorus and all combustible substances, is an imaginary creation. All the phenomena of combustion and calcination are much more readily explained without phlogiston than with phlogiston. I understand that my ideas will not be suddenly adopted. The human mind conforms to a certain manner of vision and those who during a portion of their lives comprehend nature from a given point of view have difficulty in acquiring new ideas. In good time the opinions I have set forth will be confirmed or destroyed. In the interim, it is a great satisfaction for me to see that young, unprejudiced minds among those who are commencing to study science, such as mathematicians and physicists, who have a new sense of chemical truths, no longer believe in phlogiston as presented by Stahl but regard the whole doctrine as scaffolding which is more embarrassing than it is useful for the continuance of the structure of the science of chemistry.

And the wonder of it all is that the great chemists of his time outside of his own country persisted in their narrow point of view. Priestley and Cavendish refused to be converted. Scheele,[19] in 1783, wrote:

> Is it impossible to convince Lavoisier that his system will not find universal acceptance? The idea of nitric acid from nitrous air and pure air, of carbonic acid from carbon and pure air, of sulphuric acid from sulphur and pure air,

[16] Thorpe: Essays in Historical Chemistry, 1890, p. 170.
[17] Oeuvres de Lavoisier, Paris, 1862, 2, p. 334.
[18] Oeuvres de Lavoisier, Paris, 1862, 2, p. 623.
[19] Scheele's Briefe, p. 364.

of lactic acid from sugar and pure air ! ! Can one believe such things? Rather will I support the English.

Only Black, professor of chemistry at Edinburgh and the discoverer of "fixed air," saw the truth. Lavoisier wrote to Black on Nov. 13, 1790, a letter [20] composed six months after the reading of his last memoire to the Académie des Sciences. He concluded the letter with the truest French courtesy:

It is only right that you should be the first to be informed of progress in a field which you opened and in which we all regard ourselves as your disciples. We do the same kind of experiments and I have the honor to communicate to you the results of our recent discoveries. I have the honor to remain, with respectful attachment, etc.

And to this Black replied in 1791:

The numerous experiments which you have made on a large scale and which you have so well devised have been perused with so much care and with such scrupulous attention to details that nothing can be more satisfactory than the proofs you have obtained. The system which you have based on the facts is so intimately connected with them, is so simple and so intelligible, that it must become more and more generally approved and adopted by a great number of chemists who have long been accustomed to the old system. . . . Having for thirty years believed and taught the doctrine of phlogiston as it was understood before the discovery of your system, I for a long time felt inimical to the new system which represented as absurd that which I had hitherto regarded as sound doctrine, but this enmity which springs only from force of habit has gradually diminished, subdued by the clearness of your proofs and the soundness of your plan.

In reading of the overthrow of the old doctrine of the fire principle phlogiston, one must feel a throb of the impending horror of the French Revolution when one considers the statements of Marat, written in 1791. Marat at one time had declared that a flame, when placed in a confined vessel, went out because the heat of the flame suddenly expanded the air, causing such a pressure on the flame that it was extinguished. Lavoisier refuted this doctrine. Marat, "L'Ami du Peuple," under the title "Modern Charlatans," published the following:

Lavoisier, the putative father of all the discoveries that are noised about, having no ideas of his own, snatches at those of others, but having no ability to appreciate them, he quickly abandons them and changes his theories as he does his shoes.[21]

[20] Richet: Revue Scientifique, 1887, 39, p. 193.
[21] Grimaux: Lavoisier, 1896, p. 207.

Certainly words of unqualified, contemporaneous disapproval!

Lavoisier's new system of salts and oxides led him to forecast the discovery of sodium and potassium, for in his "Elements of Chemistry"[22] he wrote: "It is quite possible that all the substances we call earths may be only metallic oxides irreducible by any hitherto known process." A eulogist of Lavoisier has likened this to the vision of Copernicus before Galileo's invention of the telescope.

Lavoisier had now progressed so that he was able to lay the fundamental basis of modern chemical physiology. Thus, in 1785, he stated that the discrepancy between the quantity of expired carbonic acid and inspired oxygen, which he had observed in 1780, was accounted for by the fact that a part of the absorbed oxygen was utilized to oxidize hydrogen in the lungs. This oxidation would produce additional heat and account for the discrepancy between the heat directly measured from a guinea-pig and the heat calculated as being derivable from the oxidation of carbon by oxygen. It is interesting to recall that eighty years later, in 1860, Bischoff and Voit[23] still calculated the heat value of the metabolism from the heat which would be produced in burning the carbon and hydrogen elements of the metabolism.

Respiration experiments on a human being constituted the final contribution in the culmination of this great career. The work is presented by Seguin and Lavoisier[24] in the memories of the Académie des Sciences during the year 1789. In this paper the authors remark:

> This analogy between combustion and respiration did not escape the attention of the poets and philosophers of antiquity, of which they were the interpreters and spokesmen. Fire taken from the heavens, this flame of Prometheus, not only represents an idea that is ingenious and poetical but it is a true picture of the operations of nature on behalf of animals who respire; one can say with the ancients that the fire is lighted the moment a baby takes its first respiration and is not extinguished until its death.

Before giving the details of the experiments on man the authors state that a guinea-pig respired in pure oxygen and in a mixture of oxygen and hydrogen gas just as it did in ordinary air; respiration, circulation and the intensity of combustion were uninfluenced. Nitrogen had nothing to do with respiration.

[22] Lavoisier: Elements of Chemistry, Philadelphia, 1799, p. 218.
[23] Die Gesetze der Ernährung des Fleischfressers, Leipzig, 1860, p. 43.
[24] Oeuvres de Lavoisier: Paris, 1862, 2, p. 688.

In the experiments on man Seguin himself was the subject. The results were:

TABLE 1

RESULTS OF EXPERIMENTS ON MAN

Condition	Environmental Temperature, Degrees	Oxygen Absorbed per Hour
(1) Without food	26	1,210 pouces de France
(2) Without food	12	1,344
(3) With food		1,800-1,900
(4) Work (9,195 foot pounds) without food		3,200
(5) Work (9,750 foot pounds) with food		4,600

Here are the basic facts regarding metabolism. The basal metabolism was increased 10% after exposure to cold; 50% after taking food; 200% by exercise, and 300% on combining the influences of food and exercise. We now know more details and we may also calculate that Lavoisier's determination of 24 liters of oxygen absorbed per hour in this first historical experiment on the basal metabolism was 25% too high. As for the experimental plan, it is as modern as the work of today and yet it was executed 140 years ago by the first man who really understood the significance of oxygen. It is only in the last decade that the summation of the individual stimuli caused by food and muscular work and noted by Lavoisier has been verified. Lavoisier also observed a constant relation between the quantity of oxygen consumed and the rate of the pulse multiplied by the number of respirations.[25]

How Lavoisier achieved these remarkable results is not known, for the times in which he lived became too troubled to allow further work in pure science. We find, however, the following statement in the original memoire:

> It would have been impossible to accomplish these exact experiments upon respiration before the introduction of a simple, easy and rapid method of gas analysis. This service M. Seguin has rendered to chemistry.

If one turns to the report of Seguin,[26] one finds that he states that in his work with Lavoisier he used eudiometers 8 to 10 inches high and an inch in diameter in order to determine the "vital air" or oxygen in the respired air. The tube was first filled with mercury and inverted over mercury, a little of the gas to be analyzed was introduced and

[25] Letter to Black: Revue scientifique, 1887, 39, p. 193.

[26] Annales de Chimie, 1791, 9, p. 293.

then a bit of phosphorus which was later ignited by bringing a burning ember in the vicinity of the glass. The rest of the air to be analyzed was gradually admitted, and when the tube cooled the volume of the air remaining could be measured. The loss in volume represented the quantity of oxygen absorbed. Carbonic acid could then be absorbed by potash. Seguin stated that the older method, as originally introduced by Priestley, had twenty sources of error but that his method merited attention on account of the very great exactitude with which he could determine the gases which are contained in respired air.

He furthermore truly states:

> If we enter into a room containing a large number of people we immediately smell a strong, suffocating odor, but if we use eudiometers to analyze this foul air and compare it with ordinary atmospheric air we find hardly any difference in the proportions of gases which are contained in them.

After Lavoisier's death, Madame Lavoisier drew from memory the apparatus used by her husband. There are two pictures, quite dissimilar. Good reproductions are to be found in Grimaux's "Lavoisier." In both pictures Seguin sits naked in a chair, breathing through a mask into a series of globes or bell jars. In both pictures Madame Lavoisier is shown seated at a table, taking notes of the experiment. In both pictures the pulse is being counted. In one experiment a weight is placed on Seguin's instep. The arrangement of the apparatus is quite different in the two pictures. In the experiment showing Seguin at work it seems as though valves were indicated through which inspired air was received from the atmosphere while the expired air was driven through a tube into a bell jar under water. Nysten,[27] working in Paris, in 1811, described the method by which he caused tuberculous and other patients to respire through valves into a previously collapsed bag for half a minute and then analyzed the expired air by a method similar to that of Seguin.

These are the known historical facts about the apparatus used in the first respiration experiments on man, but the exact details of the method by which results were established and which still are the basis of metabolism studies are unknown.

In contemplating his results Lavoisier said:

> This kind of observation suggests a comparison of forces concerning which no other report exists. One can learn, for example, how many pounds of

[27] Archiv für die Physiologie, Berlin, 1817, 3, p. 286.

weight-lifting correspond to the effort of one who reads aloud or of a musician who plays a musical instrument. One might even value in mechanistic terms the work of a philosopher who thinks, the man of letters who writes, the musician who composes. These factors, which have been considered purely moral, have something of the physical and material which this report allows us to compare with the activities of a man who labors with his hands. It is not without justice that the French language has united under the common expression *work* the effort of the mind with that of the body, the work at the desk with the work at the shop. . . .

Thus far we have considered respiration only as a consumption of air, the same kind for the rich as for the poor, for air belongs equally to all and costs nothing. The laborer who works enjoys indeed in great measure this gift of nature. But now that experiment has taught us that respiration is a true process of combustion which every instant consumes a portion of an individual, that this combustion is greater when the circulation and respiration are accelerated and is augmented in proportion to the activity of the individual life, a host of moral considerations suggest themselves from these determinations of physical science.

What fatality ordains that a poor man, who works with his arms and who is forced to employ for his subsistence all the power given him by nature, consumes more of himself than does an idler, while the latter has less need of repair? Why the shocking contrast of a rich man enjoying in abundance that which is not physically necessary for him and which is apparently destined for the laboring man? Let us take care, however, not to calumniate nature and accuse her of faults undoubtedly a part of our social institutions and perhaps inseparable from them. Let us be content to bless the philosophy and humanity which unite to promote wise institutions which tend to bring about equality of fortune, to increase the price of labor, to assure to it just recompense, to offer to all classes of society and especially the poor more pleasures and greater happiness. Let us trust, however, that the enthusiasm and exaggeration which so readily seizes men united in large assemblies, that the human passions which sway the multitude, often against their own interest, and sweep the sage and the philosopher like other men into their whirlpool, do not reverse an outlook with such beautiful vistas and do not destroy the hope of the country. . . .

We end this memoire with a consoling reflection. To merit well of humanity and to pay tribute to one's country it is not necessary to take part in brilliant public functions that have to do with the organization and regeneration of empires. The naturalist may also perform patriotic functions in the silence of his laboratory and at his desk; he can hope through his labors to diminish the mass of ills which afflict the human race or to increase its happiness and pleasure; and should he by some new methods which he has opened up prolong the average life of men by years or even by days he can also aspire to the glorious title of benefactor of humanity.

These are words written by the greatest scientist of his day under the spell of the French Revolution. They are words of an educated, cultivated man of middle age, spoken in the Académie des Sciences in the year of the fall of the Bastile and at a time when Edmund Burke

from the other side of the Channel said: "In the groves of their Academy at the end of every vista you see nothing but the gallows."

And in 1790, a year later, Lavoisier [28] concluded his last scientific communication to the Académie with these words:

> Up to the present time we have learned only to conjecture as to the cause of a great number of diseases and as to the means of their cure. Before hazarding a theory we propose to multiply our observations, to investigate the phenomena of digestion and to analyze the blood both in health and in disease. We will draw upon medical records and the light and experience of learned physicians who are our contemporaries and it will be only when we are thus completely armed that we will dare to attack a revered and antique colossus of prejudice and of error.

No person of understanding can escape a thrill at this vision of modern medicine expressed by him who had overthrown phlogiston, discovered the composition of the air and its relation to combustion and to life, and who had created calorimetry and revolutionized the whole of chemical thought.

True to his enthusiasm we find him drawing up the conditions for an international prize of 5,000 livres offered by the Académie des Sciences in 1792 to the author of the best experimental treatise on the liver and the bile.[29]

Lavoisier's life outside his laboratory had been that of a public official, a tax gatherer, and he had also been associated with the national manufacture of gunpowder, the quality of which he had greatly improved. He purchased a large landed estate and made experiments in scientific agriculture, doubling the wheat crop, quintupling the number of beasts on the land and earning thereby the enduring gratitude of the peasants.

However, as stated before, he had incurred the bitter hatred of Marat, and he was a tax gatherer. In November, 1793, he was arrested in his laboratory at the Arsenal, on which he had spent a large portion of his fortune. A little while before, in August of the same year, the Académie des Sciences had been closed as inimicable to the welfare of the state. This institution had been established in 1666 by Louis XIV who, after the peace of the Pyrenees, in the fulness of his power, felt that his kingdom needed nothing further than to be fortified by science, industry and art, and he intrusted his minister

[28] Oeuvres de Lavoisier, Paris, 1862, 2 p. 704.
[29] Oeuvres de Lavoisier, Paris, 1862, 6, p. 33.

Colbert to carry out his desires.[30] But les amis du peuple are notoriously suspicious of the "intelligenzia," and the Académie was abolished.

Just prior to his execution Lavoisier wrote to a friend:

> I have had a sufficiently long career, always a very happy one, and I believe that my memory will be thought of with some regret and perhaps as having something of glory. What more could I desire? The circumstances which surround me would probably lead to an uncomfortable old age. . . . It is certainly true that all the social virtues, important services to the country, a useful career employed in promoting art and human knowledge, have not sufficed to save me from a sinister end or to prevent me from perishing as a criminal.

One of the charges against Lavoisier was that he had allowed the collection of taxes on the water contained in tobacco. On May 8, 1794, at the age of 50 years, he was tried and found guilty. Twenty-eight fermiers-generaux were executed in the Place de la Republique at the same time. He witnessed the execution of his father-in-law, Paulze, who was fourth on the list, and he was the fifth upon whom the ax of the guillotine fell.

Such was the Terror.

His friend, Lagrange, whispered that night to an intimate, "It took but an instant to cut off his head; a hundred years will not suffice to produce one like it!"

Writing a hundred years later, Berthelot [31] exclaimed:

> It is our right to admire the positive work which he accomplished. The universal judgment of the civilized world increasingly reveres his establishment of chemistry, one of the fundamental sciences, upon a fixed and definite basis. There is no grander accomplishment in the history of civilization and hence the name of Lavoisier will live forever in the memory of humanity.

It is interesting to consider the differences in the lives of the men concerned in the great discoveries of the last quarter of the eighteenth century. Priestley, an indigent clergyman; Cavendish, of whom it was said that he was the most wealthy of learned men and the most learned of the wealthy; Scheele, a poor Swedish apothecary; and Lavoisier, a man of affairs, a noble of high social position in receipt of huge personal revenues. What is it, then, that makes for greatness in science? Would Lavoisier have accomplished more had he been on a "full-time" basis with a restricted income? It is a question of individual opinion,

[30] Oeuvres de Lavoisier, Paris, 1862, 4, p. 557.
[31] Berthelot: La Revolution Chimique, Paris, 1890, p. 207.

but to most people it would appear that scientific greatness depends primarily on the quality of the intellectual protoplasm of the brain, on the advantages offered to the functioning of that brain, and on the possession of a good conscience. These factors and not a coerced limitation of income are the driving forces toward the revelation of scientific truth.

Let us pass from the Paris in which Lavoisier was executed to the Paris which Liebig visited about a quarter of a century later. In the interim Napoleon had come and gone. Berthollet, an associate of Lavoisier, had taught Napoleon chemistry. Berthollet and Monge, the mathematician, had organized a company of one hundred scientists to accompany Napoleon to Egypt. Pasteur,[32] in looking into certain records, found that after Waterloo Napoleon, conversing with Monge at the Elysée, said: "Condemned now no longer to command armies, I see only Science with which to occupy my mind and my soul."

In the year 1823 Berzelius lived in Sweden, Davy in England, Volta in Italy, but in Paris lived Laplace, Berthollet, Guy Lussac, Thénard, Cuvier, Ampère and Magendie. Thorpe,[33] today president of the British Association for the Advancement of Science, writes:

> That constellation has set—
> "the world in vain
> Must hope to look upon their like again."

Into this circle both Liebig and Dumas were introduced by Alexander von Humboldt. Liebig, dedicating a French edition of one of his books to Thénard, a former master, thus expresses his appreciation:

> To Monsieur le Baron Thénard,
> Member of the Académie des Sciences:
>
> Monsieur:
>
> In 1823 when you presided over the Académie des Sciences a young foreign student came to you and begged you to advise him concerning the fulminates which he was then investigating.
>
> Attracted to Paris by the immense reputation of those celebrated masters whose glorious researches established the foundations of the sciences and elevated them into an admirable edifice, he had no other introduction to you except his love of study and his fixed desire to profit from your teachings.
>
> You bestowed on him a most encouraging and flattering welcome, you directed his first researches, and through your influence he had the honor to communicate them to the Académie.

[32] Vallery-Radot: The Life of Pasteur, 1902. 1, p. 257.
[33] Essays in Historical Chemistry, 1902, p. 328.

It was the session of the 28th of July which decided his future and opened a career in which for seventeen years he has labored to justify your benevolent patronage.

If his labors have been useful, it is to you that science is indebted for them, and he feels obliged to express publicly to you his ineffaceable sentiments of gratitude, esteem and veneration.[34]

JUSTUS LIEBIG.

Giessen, 1 January, 1841.

This was also the day of the French clinician Pierre Charles Alexandre Louis, whose American pupils included Oliver Wendell Holmes, Gerhard, the Shattucks and the Jacksons.

In the following years the brilliant Dumas, single handed in France, was continually entering the lists against his more methodical contemporaries, Liebig, Wöhler and Berzelius.

At the time Liebig and Dumas began their scientific carrers in Paris, Claude Bernard was a youth of 10 and Pasteur had been born the year before. Later, when Bernard was at the height of his intellectual power, some one asked Dumas, "What do you think of this great physiologist?" To which Dumas replied, "He is not a great physiologist. He is Physiology itself."

Pasteur was a pupil of Dumas, and when the Académie des Sciences in 1882 decided to confer a special medal on Pasteur, Dumas headed a chosen delegation and in his address to Pasteur said:

My dear Pasteur, your life has known only success. The scientific method which you use in such a masterly manner owes you its greatest triumphs. The Ecole Normale is proud of your work. France ranks you amongst her glories.

And in reply Pasteur said:

My dear Master, it is indeed forty years since I first had the happiness of knowing you and since you first taught me to love science.

I was fresh from the country; after each of your classes I would leave the Sorbonne transported, often moved to tears. From that moment your talent as a professor, your immortal labors and your noble character have inspired me with an admiration which has grown with the maturity of my mind.

In this fashion one can trace history from generation to generation, the influence of the individual master on the fruitful soil of a younger mind. The wonder working changes wrought by Pasteur have been thus expressed by Osler:

[34] Dedication to French edition of "Chimie organique appliqués á la physiologie végétale et a l'agriculture," Paris, Fortin, Masson & Co., 1841.

At the middle of the last century we did not know much more of the actual causes of the great scourges of the race, the plagues, the fevers and the pestilences, than did the Greeks. Here comes in Pasteur's great work. Before him Egyptian darkness; with his advent a light that brightens more and more as the years give us ever fuller knowledge.

Hear this cry of Pasteur [35] which followed the defeat of France in 1870 concerning "the forgetfulness, disdain even, that France had had for great intellectual men, especially in the realm of exact science." He says:

Whilst Germany was multiplying her universities, establishing between them the most salutary emulation, bestowing honors and consideration on the masters and the doctors, creating vast laboratories amply supplied with the most perfect instruments, France, enervated by revolutions, ever vainly seeking the best form of government, was giving but careless attention to her establishments for higher education.

The cultivation of science in its highest expression is perhaps even more necessary to the moral condition of a nation than to its material prosperity.

Last summer in Paris the illustrious president of the Physiological Congress of 1920, Charles Richet, in his opening address said: "Seek to understand things; their utility will appear later. First of all it is knowledge which matters." And he illustrated this by citing the investigations of Claude Bernard on the glycogenic function of the liver and the investigations of Portier and himself on the subject of anaphylaxis which they carried on with poisons of sea anemones injected into birds while they were sailing through tropical waters on the yacht of Prince Albert of Monaco.

It is well for us to learn lessons from the great masters of the past. Carl Voit, in 1890, said to me: "Die Franzosen sind ungeheur begabt aber die jeztzige traurige politische Verhältnisse drücken sie nieder." If we can only learn what the conditions are for the production of scientific men and provide such conditions, the world will gain hugely. A well-known British scientist said to me during the war:

The Greeks had no classical education but they had the two essentials of true education, first, the ability to express themselves correctly in words and second, to appreciate their own relation to their surroundings, which latter is science.

It is in this sense that Lavoisier and Pasteur brought understanding into the minds of men, and this makes it a rare honor and a privilege to speak of them in the first Pasteur Lecture.

[35] Vallery-Radot: Life of Pasteur, 1902, 1, p. 256.

DISEASES OF THE MOUTH AND GENERAL HEALTH

PRESIDENT'S ADDRESS

THOMAS L. GILMER

Dec. 7, 1920

The mouth is subject to as great a variety of diseases as any other part of the body, although their multiplicity and importance are often not fully recognized. I am venturing to invite your attention to some of these affections of the mouth in their relation to diseases elsewhere in the body, in the hope that the discussion may not only prove of interest, but that attention may be directed to some of the problems of the day which await solution, especially that related to the elimination of certain oral conditions of children which may affect their physical and mental well-being through life. Before adverting to these matters, however, I wish to discuss briefly the relation of disease of the mouth to general disease and to present certain views which, while not entirely in harmony with current opinion, are derived from my own experience.

Diseases of the mouth are either local in character or they may constitute part of the picture of general diseases, the primary lesion of which may be oral or situated elsewhere in the body.

Mucous patches and gumma of syphilis, Koplik spots of measles, the strawberry tongue of scarlet fever, and the petechial spots of purpura hemorrhagica are oral manifestation of general diseased conditions in other parts of the body. Lesions of the kidney, also, are often associated with pathologic changes in the mouth. When albumin is found in the urine of pregnant women, the gums often become hyperemic, swollen, tender and bleed easily on being touched. This condition of the gums disappears soon after parturition. The non-malignant tumor, improperly called epulis, when found in the mouth of pregnant women, increases in size more rapidly during the later months of pregnancy, and after delivery, it decreases to about its former size.

Senile changes are always more or less reflected in the mouth by rapid wasting of the gums. Similar changes are also seen in the mouths of men past middle life who have long been subjected to the

strain of business and its attendant cares and anxieties. As a result of destruction of the gums, deep pockets are formed between the teeth in which accumulate debris from wasting tissues, together with food and bacteria. Teeth which have resisted disease up to this time, now decay rapidly on surfaces exposed within these pockets.

Secondary and tertiary syphilitic manifestations in the mouth are too well known to require more than passing mention. It is also well known that syphilis may appear primarily in the mouth, and there are a number of oral diseases which are sometimes mistaken for syphilis. Carcinoma of the mouth in its earlier stages has the appearance of syphilis, and indeed is believed in certain cases to develop on the site of previous syphilitic leukoplakia, and to add to the confusion a positive Wassermann reaction may be found. Chronically infiltrated ulcers of the buccal mucosa due to injuries caused by malposed teeth and by teeth having sharp edges are occasionally seen. These ulcers are covered with a grayish-white film which suggests syphilis. Removing or changing the relation of the teeth, or smoothing their sharp edges, brings about a cure. Gonorrheal and chancroidal infections are found in the mouth.

Leukoplakia of the mouth is an interesting disease. Evidently there are two forms. One is transitory, coming on suddenly, and disappearing without treatment; the other does not disappear spontaneously, and generally has a history which indicates that it is of syphilitic origin. Both are white in appearance, but the latter is a less intense white, and is more widely distributed over the mucous membrane.

Herpes of the mouth, commonly called canker sores, are frequently seen on the buccal mucosa. They appear suddenly and are extremely painful, and are not infrequently associated with gastro-intestinal disturbances. For some as yet unknown reason women are far more subject to them than are men. Actinomycosis is found in the mouth, and decayed pulpless teeth offer a convenient nidus for its implantation.

Another disease definitely primary in the mouth became prevalent among the soldiers during the World War. It is an infection of the gums, known as "trench mouth." Some thought this a new disease, but it had been recognized many years before, and was described in 1906, and named "acute ulcerous gingivitis." [1] Since then it has received many names. Weaver and Tunnicliff call it "ulceromembranous gin-

[1] Dental Review, 1906, 20, p. 459.

givitis." Later Tunnicliff isolated the predominating organism accompanying this disease for me and found it to be the Bacillus fusiformis. This organism is of special interest since it is so often found in various other lesions, and it frequently grows symbiotically with other organisms. Infections starting at the angle of the jaw and extending to the floor of the mouth, causing diffused cellulitis, known as Ludwig's angina, seem to be due to the streptococci, in association with this organism. Prior to the war acute ulcerous gingivitis was rarely seen. After demobilization it was prevalent for a time, having apparently been communicated in many instances by the exsoldiers to those who had not been in the army. It is now disappearing rapidly.

Hunter is of the opinion that septic mouths are the cause of what he calls "septic anemia." Glossitis or ulcers of the tongue and mucosa are practically always present at some time in the course of progressive pernicious anemia.

Neoplasms of the mouth are definitely primary there, and should be considered in this connection. Partsch has stated that 90% of all neoplasms which affect the jaws belong either to the carcinomas or sarcomas, of which the former comprise 53% and the latter 37%. It would seem that these figures are excessive, especially for the sarcomas, unless they include those benign growths, known as epulis, and the nonmalignant myeloid or giant-celled sarcoma. Epulis is a fibrous connective tissue growth with some of the histologic appearances of giant-celled sarcoma. Epithelioma and the malignant sarcoma are prevalent in the mouth, and the former apparently is becoming more common. Most pathologists believe that chronic mechanical irritation plays an important rôle in the causation of epithelioma, and there is evidence in favor of this belief, but my experience, which may have been unusual, indicates that the importance of mechanical chronic irritation has been overestimated. During the past three years I have seen, in my private practice, 29 cases of epithelioma of the mouth, and of this number only 8 might supposedly be attributed to mechanical injury. Nine of the growths were associated with leukoplakia. Twenty-seven of the patients were males and two were females. My clinic histories of patients who had epithelioma are not sufficiently reliable to justify an estimate of the number of these tumors which could be attributed to mechanical injury, or to the frequency of leukoplakia as an accompaniment to them, but I am of the opinion that

they do not differ materially from those seen privately. The surgeon may be led astray by the history of these growths given by the patient. He is often told that a certain sharp tooth has caused the disease, but careful examination usually discloses the fact that the primary lesion could not, in its incipiency, have been in contact with the accused tooth. Epithelioma is not usually sensitive in its earlier stages and therefore is not noticed by the patient until the growth has extended beyond its original location. As a result of the increased development of the neoplasm, the tooth later comes in contact with the increasingly inflamed and therefore more sensitive area, and then for the first time it is noticed by the patient, who naturally attributes it to the tooth. If chronic irritation were the most common cause of epithelioma, it would seem that irritation due to nose glasses would result in this disease. I have never known a case of epithelioma which was caused by irritating nose glasses, and ophthalmologists of wide experience have informed me that they also have not known such a case. Evidence is gradually accumulating which seems to indicate that heat is a factor in the cause of cancer—not a sufficient degree to produce burns, but a rather high heat frequently applied.

Sarcoma of the mouth is not uncommon in young people and children and occasionally is seen in the mouths of older persons. The round and spindled-celled varieties in the mouth are very malignant and much inclined to form metastasis, while the giant-celled or myeloid type does not cause metastasis, and in this respect is not of itself malignant; it is, however, very destructive of bone.

Mixed tumors, largely composed of glandular structure, are found in the hard and soft palate. They are always unilaterally placed, encapsulated, and not malignant. Lipoma is found in the cheek; angioma on the lips and gums; and papilloma on the palate and other localities in the mouth. Odontoma and adimantinoma of the jaws are attributed to epithelial rests, from unatrophied parts of the cord of the enamel organ. Retention mucous cysts, in the floor of the mouth, known as ranula, also, muciperous cysts of the lips, cysts of the Bland and Nuhn gland, and dentigerous cysts are an interesting group of tumors found in the oral cavity. Stones are occasionally found in Wharton's and Stenson's ducts. Evidence seems to indicate that these calcareous deposits are formed in the salivary glands and are extruded into the ducts, where they enlarge from additions received from the

lime of the salivary secretions. Bilateral exostoses are frequently seen on the lingual surfaces of the mandible in the region of the bicuspids. Occasionally they grow to considerable size, extending from the one side toward the other until they nearly meet. A similar growth is seen in the median line of the hard palate. Their removal is rarely indicated.

Tuberculosis is generally supposed to be secondary in the mouth, due to an extension of the disease from lupus on the face or lips, or from tuberculosis of the lungs. I have seen several cases in which tuberculosis seemed to be definitely primary in the mouth. In two of these the disease had attacked the tongue. There was a soft ulcerated area with ragged undermined margins, and a surface coating of a grayish-white layer. These ulcers are extremely tender, and in this respect differ from carcinoma. Multiple miliary tuberculosis is occasionally found in the mouth, studding the surface of the buccal mucosa.

The physician's interest in diseases of the mouth was increased when our own Billings, Hunter of England, and others showed the relation between tonsils and chronic oral infections of the teeth and jaws and diseases in other parts of the body. With few exceptions their statements have been accepted in full, or in modified form, but some members of the medical and dental professions have gone far beyond the claims of either Billings or Hunter, and attribute almost every conceivable bodily ill to the teeth and tonsils, when the symptoms do not definitely point elsewhere.

The two infections of the mouth which are instrumental in causing secondary disease are chronic alveolar abscess and pyorrhea alveolaris, the latter, a disease only in the adult. Their prevalence is indicated by a study made by Dr. Arthur D. Black, of 6,000 radiographs of 600 adults' jaws, taken without reference to the condition of the teeth or health. He found 78% had either chronic alveolar abscesses or pyorrhea, 55% having alveolar abscesses and 53% pyorrhea.[2]

There are two kinds of chronic alveolar abscesses, the encapsulated or walled off variety and another kind which has no capsule. The latter is filled with infected granulation tissue, having direct communication through the lymphatics and blood vessels with the adjacent healthy bone. The dissemination of dangerous germs is more likely to occur from the nonencapsuluated variety. Chronic alveolar

[2] Jour. Am. Med. Assn., 1918, 71, p. 1279.

abscesses occasionally have sinuses opening on the gums, face and into the maxillary sinus. A large percentage of antral infections are due to abscessed teeth.

Primarily pyorrhea is a disease of the peridental membrane and, with the exception of dental decay, is the most common mouth lesion. While the greater part of the pus and bacteria from pyorrheal pockets is discharged into the mouth, there is reason to believe that some of the bacteria may enter the blood and lymph channels directly from the pus pockets. Dr. Hatton of the Research Department at Northwestern University Dental School was able to demonstrate bacteria in the walls of pyorrheal pockets, and in the peridental membrane, usually perivascular in position.[3] In addition to the open infected areas, foci of infection are found in the peridental membrane far beyond the bottom of pyorrheal pockets, the bacteria having reached these isolated positions through the lymph channels in the peridental membrane. Such infections at times develop acute exacerbations which later become chronic and remain definitely closed infected processes.

If all of the teeth in the jaws had apical abscesses, the combined infected areas would be much less than if all of the teeth were involved in pyorrhea. In addition to the dissemination of bacteria from pyorrheal pockets through the lymphatics and blood vessels during the progress of the disease, there is discharged into the mouth much bacteria-laden pus, which is swallowed. There is difference of opinion as to whether the pus and bacteria from this source cause gastro-intestinal disturbance, but reports of cures of such diseases following the elimination of extensive pyorrheal pockets, may justify the assumption that pyorrhea does contribute to gastro-intestinal disease. Oral sepsis, according to Hunter, is a potent and persistent cause of septic gastritis.[4] Hunter also believes that what he terms "septic anemia" is due to oral infection, and Osler makes similar statements.[5] Since pyorrhea offers a greater area of infection than chronic alveolar abscess, and since it may at times be a closed process, it may be a greater menace to health, and therefore, it should receive due consideration in seeking the cause of disease, the etiology of which is obscure.

When we revert to the researches of Vaughan, Koessler, Walker and others, concerning the toxicity of various proteins and their split

[3] Jour. Am. Med. Assn., 1918, 71, p. 1549.

[4] Pernicious Anaemia, p. 233.

[5] Osler and McCrae: Modern Medicine.

products and their relation to hypertension and other disturbances, the importance of infections about the teeth is still further emphasized. The fact that deep pyorrheal pockets afford easy entrance for the products of infection into the blood is not to be overlooked, and a survey of the mouth for possible lesions should be included in the medical management of all such cases.

Evidence at hand showing the relation between chronic oral infection and secondary disease is too positive for refutation, and cannot be too strongly emphasized, but the indiscriminate removal of teeth and tonsils, without positive evidence of their being the cause of secondary disease, is unwarranted and unfair to patients. Through newspaper propaganda and the claims of over-enthusiastic physicians and dentists, many people have been thrown into a state of panic, and thinking their health jeopardized by their teeth and tonsils, are requesting their removal, independent of medical advice.

Some dentists and some physicians, who have not properly considered the subject, seem to have lost all sense of perspective, as a result of having too closely focused their attention on the teeth and tonsils in seeking the cause of disease, to the exclusion of other parts of the body having equal or greater infected areas; also, by attributing certain illnesses to chronic infections which are not dependent on them. It is as unscientific to attribute all cases of neuritis and arthritis to pulpless teeth, regardless of whether they are infected or not, as to attribute all bronchial asthma to polypoid growths in the ethmoid cells. Moreover, errors are occasionally made in attributing certain diseases to abscessed teeth in cases in which a carefully taken history would have disclosed the fact that the onset of the disease antedated the death of the pulps of the teeth.

Some dentists have been led to believe that the white cell blood count, especially, varies in arithmetical progression with the number of pyorrheal pockets of a certain depth, also with the number and extent of chronic alveolar abscesses as indicated by radiographs. In my clinic, Dr. Hatton has been able to demonstrate the evident absurdity of such notions by the examinatiion of several hundred patients having alveolar abscesses, pyorrheal pockets, and other mouth diseases Leukocyte counts furnish information of value only in exceptional cases of mouth conditions, and the leukocyte reaction is not in any essential different from that due to infection elsewhere in the body.

Indiscriminate removal of tonsils is reprehensible, but their loss, so far as known, is inconsequential as compared with the loss of teeth.

It would be unfair to impugn the motives of some dentists who daily remove many teeth, or some rhinologists who remove many pairs of tonsils, but one naturally wonders if there is not danger of the practice becoming commercialized.

There are two terms commonly used by some physicians and some dentists, which should be eliminated, since they give erroneous impressions. These are "dead teeth" and "nonvital teeth." Usually dead or nonvital teeth are abhorrent to adjacent live tissues, and when present, eliminating forces are at once set up for their removal. What really is meant by those who improperly use these terms is not that the teeth are wholly devoid of life, but that they are pulpless.

The pulp of a tooth is the formative organ of the dentine and is transitory. If one lives to very old age it disappears; the tooth still lives since the cementum of the root receives its nutrition wholly from the peridental membrane. The death of the pulp affords opportunity for apical infection, but if the root canal of a pulpless tooth is made aseptic and is hermetically sealed, the root does not usually become infected and alveolar abscess does not follow. This refutes the statement that "all pulpless teeth are a menace to health." If the peridental membrane of a tooth is completely destroyed, the tooth becomes necrosed, and then and only then does it become a "nonvital" or "dead" tooth.

If only a limited part of the cementum about the apex of the root has been denuded of its peridental membrane, as the result of an alveolar abscess, the condition may generally be cured by disinfecting and filling the root canal, and in other cases, even though a considerable part of the cementum is denuded, it may be cured by resecting the dead cementum and draining the infected area. Prior to this operation, the root canals must be disinfected and filled. Because of anatomic reasons, resection of roots is usually restricted to the eight anterior teeth. As remarkable cures of secondary diseases dependent on abscessed teeth have been brought about by root resection and thorough drainage, as have been made by the extraction of similarly infected teeth.

There is much unwarranted, spectacular operative procedure called "surgery," which removes all adjacent osseous tissue in connection with

removal of abscessed and pyorrheal affected teeth. In some cases where there has been extensive bone destruction, operative procedures may be indicated, but ordinarily the removal of the tooth suffices. The examination of 2,000 radiographs of edentulous or partially edentulous jaws, taken for me in my clinic and private practice, in which no curettement or surgical procedures had been observed, revealed only three alveolar abscesses which had persisted after the teeth had been removed. The removal of granuloma, especially if extensive, may hasten recovery and in some instances is indicated, but too much surgery has led to diffusion of bacteria through adjacent tissues with serious results.

I might incidentally refer to the use of radiographs in connection with abscesses of the jaw. The radiograph offers means of determining the extent and location of chronic alveolar abscesses. However, it must not be forgotten that radiographs are only shadow pictures and are often deceptive. The angle of exposure materially changes the shadow, giving different representations of the same thing. If one depends wholly on radiographs to determine such conditions, he may be led to wrong conclusions. For instance, occasionally a radiograph indicates deep pyorrheal pockets which, when the mouth is examined, are not found. The gums as well as the alveolar process have become atrophied at the same time, and as a result much of the necks of the teeth are exposed, giving the appearance in the radiograph of pyorrhea, which does not exist. Occasionally the shadow of the maxillary sinus is mistaken for a cyst or abscess; the mental foramen may also be mistaken for an abscess. A knowledge of the anatomy and histology of the oral tissues, coupled with experienced observation, is necessary for the proper interpretation of radiographs of teeth.

Sir James Mackenzie [6] has well said: "Disease is rarely recognized until it has impaired the health of the individual and produced suffering; and the concentration of attention to this stage has diverted the attention from the preceding stages," and we may add, has diverted attention from the cause that led up to the preceding stages.

We must start with the child at birth and care for him until he reaches manhood, if we would save him from many of the ills of life, since it is at a comparatively early period that causes for oral sepsis begin.

[6] The Future of Medicine.

When a child is born the enamel of the temporary incisors and cuspids is nearly complete, and that of the deciduous molars is a little less than half finished, and is fully completed 7 months after birth. Owing to this early development of the protective portion of the deciduous teeth, their structure is not influenced by diseases of childhood, and therefore are usually perfect in formation and rarely irregularly placed in the jaws. With the exception of the first molars, the deposition of lime salts forming the second set of teeth does not commence until about 12 months after birth. The first molar has usually begun at birth. About this time the incisal edge of the central incisors and the cusps of the occlusal surfaces of the first molars are laid down. The enamel of the incisors and first molars is completed between the fifth and sixth years, that of the cuspids, bicuspids and second molars between the eighth and ninth years, and the third molars about the twelfth year. It is during the period of enamel formation of the second set that disease and malnutrition injuriously affect the shape and quality of these teeth, causing defects in the enamel, which definitely correspond to the stage of development of the teeth at that period. The health of the first three years of life, so often modified by illness arising from faulty nutrition, contagious disease and other infections, frequently determines that the child whose heredity would entitle him to a perfect mouth, may have to go through life a sufferer from dental caries or deformed unsightly teeth.

Observation leads me to believe that scarlet fever, measles and other eruptive febrile diseases of childhood produce more profound defects in the teeth than do other even more depressing diseases, such as rickets or congenital syphilis. The inclusion of notched and narrowed teeth in Hutchinson's triad with interstitial keratitis and labyrinthine disease, a syndrome commonly and properly attributed to congenital syphilis, is somewhat unfortunate, since not all teeth so deformed are due to syphilis, and therefore the stigma is, in certain cases, unjustly placed on parents. If notched and narrowed central incisor teeth of the second set were always due to hereditary syphilis, it would seem that the deciduous set would likewise have shown such defects in those definitely syphilitic at birth. But as a matter of fact they do not, while their counterparts in the second set developed after birth are often defective, especially if the child has had depressing diseases or suffered from malnutrition. It would seem possible, therefore, that

defective teeth seen in syphilitic children may arise from the malnutrition associated with syphilis, but not necessarily more from syphilis than from other diseases of like duration and extent.

If teeth are grooved, pitted, or otherwise malformed when erupted, these defects afford opportunity for lodgment of food debris, and for acid-forming fungi, which produce the lactic acid that attacks the enamel and later the dentine, causing decay. Unless that part of a tooth destroyed is restored by artificial means before the pulp is exposed, the pulp dies, with alveolar abscess as an almost certain sequence.

Children rarely have dental decay until they are approaching their second birthday. This seems to indicate that the change from infant diet to a mixed diet is a factor in the production of decay in children's teeth. The studies of D. J. Davis, Jackson, Moore, and others have definitely proved that improper diet has a positive injurious influence on the gums and underlying bony structure. Scurvy, which is supposed to be due to dietetic causes, profoundly affects the same tissues. With these facts in mind, we may suppose that improper feeding changes as well the secretions of the mouth, so that certain constituents which normally inhibit the growth of acid-forming fungi are lacking, or that others are supplied, which in combination with food remaining about the teeth, give the best possible medium for bacterial growth. If this is true, we may believe that since dental decay begins with the change of diet, that error in properly balancing the diet may have much to do with decay of teeth. May we not raise the question as to the probability of improper diet being fundamental as a predisposing cause in other infections about the mouth, such as pyorrhea alveolaris, a disease the etiology of which is obscure?

Doubtless there are many other factors which cause or counteract dental decay and some of the other diseases of the mouth. Heredity probably plays an important part. There are many marked characteristics in the child's mouth which are without doubt due to heredity. The resemblance in quality and shape of the teeth and jaws of children and parents is noticeable in some families. The tendency to decay is likewise noticeable. Cleft palate, hare lip, and cancer, on the other hand, I have been unable to associate with heredity.

Of the child's first teeth, the molars are most subject to decay. If these teeth are neglected and decay, their pulps become exposed and the child suffers pain from mastication, and as a result he bolts his

food, thereby throwing an unnecessary amount of work on the stomach. Later the pulps die with alveolar infection as a certain sequence, and as a result a definite channel is opened from the infected roots to the blood stream through which pass bacteria from the mouth. Any organism which may have found temporary abode in cavities of dental decay, such as tubercle bacilli, actinomyces, and possibly other infections, may pass through these channels. Reports by Fones of the Bridgeport Schools [7] and Guthrie of the New Orleans schools show definite lessening of contagious diseases among children as a result of perfect oral hygiene.[8] One cannot but surmise, however, that the improved conditions in personal hygiene, other than that of the mouth which necessarily must accompany and result from the degree of cooperation of parents and children in attaining so great dental improvement, must have been an important factor in obtaining this striking decrease in contagious disease. Dental decay, especially if situated between teeth, forms pockets into which food wedges and decomposes, with resulting pain, infected gums and peridental membrane. As the bacteria from these infected areas, in their excursion from the mouth to the stomach, pass the tonsils, some may find lodgment there and cause disease of these organs. Others pass through the lymph channels to the submaxillary lymphatics, causing lymphadenitis. These facts apply to the teeth of adults as well as to those of children. Sweitzer, in 1909, succeeded in injecting the lymphatics of the dental pulp. In 1914, Noyes and Dewey of Chicago repeated the work of Sweitzer and, in addition, succeeded in injecting the lymphatic capillaries of the submaxillary glands of the neck through the pulps of the teeth, demonstrating the continuity of lymph channels between the tooth's pulp and the submaxillary glands, through which may pass bacteria from the mouth.[9] Odenthal reports finding submaxillary glandular swellings in 99% of all children having badly diseased teeth and only 49% in those having sound teeth.[10] Gilberti showed the prevalence of tubercle bacilli in the mouth by injecting into guinea-pigs, previously subjected to the tuberculin test, emulsion of inguinal and also of cervical glands, taken from children believed to be dead of non-tuberculous disease. Of 30 animals injected with cervical gland emul-

[7] Bridgeport School Report.
[8] Jour. Am. Med. Assn., 1920, 75, p. 1245.
[9] Dental Cosmos, 62, p. 1037, 1920.
[10] Therapie des Maladies Infectieuses, p. 256.

sion, 11 died from tuberculosis. Of those injected with material from inguinal glands, only 2 died of tuberculosis.[11]

Examination of the mouths of the children of the grammar schools in the poorer districts in Chicago showed that 98% had diseased teeth. In some, the teeth were so badly decayed that their masticating surfaces were destroyed beyond repair, and in addition, there were numerous abscesses. In some, the gums were so badly infected as a result of dental neglect that pus was being discharged from one end of the dental arch to the other. Dental caries and attendant infection of the gums, together with acute and chronic alveolar abscesses, no doubt contribute to a large extent to the malnutrition, nervous disorder and delinquency among the poor children of the city. The great question before us is: What can be done to prevent such conditions? Much has been done in the Forsyth Dental Infirmary in Boston, the Eastman Dispensary in Rochester, N. Y., and by the school authorities in Bridgeport, Conn., and in other cities.

We have only 2,500 dentists in this city and 310,481 children in our grammar schools alone. If the dentists of this city should serve the school children who never receive dental attention, they would have little time left for their private practice. The situation may be relieved by a system which has proved successful in other municipalities. This system provides for the instruction of women in the care of children's teeth. They are a part of the school faculty and are on duty throughout the school year. They are known as "dental hygienists" in some cities and "dental nurses" in others. Their duties are to clean thoroughly the teeth of the school children several times a year, to examine their teeth for dental decay and the mouth for other diseases, and to tabulate conditions found. If the child is in need of dental service, he is referred to the family dentist, if one is employed; if not, he is referred to the dental infirmary. The dental hygienists also give instruction in the care of the mouth and teeth by tooth brush drills. They inspect each child's mouth at frequent intervals to find whether he has given it proper home care. School instruction in the care of teeth does not reach the child as early in life as it should to secure the best results, but instruction of the grammar school children in the care of their teeth will tend to educate both the parents and younger children of the family in the importance of better habits of oral clean-

[11] Medical Practice Series, 1910, 3, p. 313.

liness. An effort is being made by the Social Service Bureau of Chicago to introduce oral hygiene into the day nurseries.

This work can be carried on in the most complete manner only under school board and municipal authority. The employment of dental hygienists in sufficient numbers to care properly for the pupils in all of Chicago's grammar and parochial schools would call for a heavy financial outlay, but when the gain in mental and physical condition is considered, it would seem that the state can well afford it. By putting this system into practice, the teaching force may be materially decreased, because it has been found that children who have been generally delinquent on account of diseased mouth conditions, make their grades easily, and in some instances make double promotions, after their mouths have been restored to health. The education of women to act as dental hygienists can most economically and conveniently be accomplished in the already existing dental schools, since these schools have the facilities, including teaching force and clinical material necessary for their instruction.

During the past twelve months several papers have appeared in prominent medical journals, relating to delinquency and nervous disorders in children, but in none of these was mention made of oral infection as a possible cause, though dietetics, heredity and environment were cited as etiologic factors.

We hear much of preventive medicine, but preventive dentistry must be intimately associated with preventive medicine if we would eliminate some of the more common causes of disease. Preventive medicine has not generally included hygiene of the mouth in its work and so has missed one of the most promising avenues of attack on fundamental causes of disease. Many corporations, however, have grasped the idea that unclean, unhealthy mouths are detrimental to health. The Metropolitan Life Insurance Company in its "Daily Bulletin" of April 29, 1919, says, "The services rendered by the Dental Division since its establishment in 1915, have been so curative of impaired health conditions and so permanently helpful to the employees who have taken advantage of the opportunities offered, that henceforth every Home Office will require its employees to undergo examination and cleansing of the teeth, in the Home Office, Dental Division, twice a year."

All boards of health should have one member who is a high grade dentist to superintend a corps of dentists and dental hygienists who care for the mouths of children in the grammar schools. Owing to the extension of time now demanded for the education of dentists and the requirementts of one year of college as a requisite for entrance to dental schools, there will not be as many dentists in the United States two years hence as there were a year ago, since death and voluntary retirement from practice will more than offset the number graduating in this time. There are only 48,000 dentists in the whole country, a number wholly inadequate to dental needs, if all the people recognized the importance of oral health.

We have been slow to recognize the importance of clean healthy mouths and consequently dentists have not been able to exert an influence as beneficial as they might otherwise have exerted. When we are all brought to realize fully that unhealthy mouths are a prolific cause of ill health then, and only then, will a systematic effort be made which will bring about correction of present neglect. Dentists must play an ever increasing rôle through the care of the mouth in the prevention of disease.

THE LITERARY VALUE OF HUNGER

Charles B. Reed

December 7, 1920

"Poor Goldsmith!" How often we have heard this exclamation from the lips of those who loved his writings and bemoaned his struggles against the ever present menace of starvation? How freely also the privations of Francis Thompson have been exploited to enlist a sympathetic and possibly a commercial interest. Chatterton, too, De Quincy and others come to mind who, in early life, suffered hunger, misery and affliction.

But are these men entitled to such particular commiseration? Is there not, aside from the well nigh universal necessity of working to live, is there not in hunger itself, some measure of compensatory stimulation? In the very exigencies of poverty and distress, is there not a mysterious something that urges the soul onward to a more elaborate pursuit of its elusive visions?

Occasionally, too, we hear the remark that such and such a genius should be subsidized and much pity has been wasted on this irritable brotherhood because its members have not been maintained in luxury by some public or private benevolence. The idea springs from a misconception of the conditions under which such a mind will functionate, for the converse of our thesis should also be true, and we expect to set forth that a genius, surrounded by physical comfort, would be so buried under the shields of plenitude that his creative impulses would be stifled irrevocably.

Since the race is immortal, rather than any of its units, the progressive principle of mankind instinctively uses the individual as a means of promoting its mighty ends. In the working out of an all-embracing design, the stresses of life become stimulants which impel the spirit to seek its freedom in imaginative fields where compromise is unnecessary and fetters unknown.

Among the literateurs of the past, we find numerous instances, too numerous to be accidental, in which the work which brought renown was done during a period of hardship. It is highly probable, moreover,

that those productions would have been inferior, or even negligible, if the authors had lived in ease. At all events they would not have reached the rank of genius. "The air of the fireside," says Stevenson, "withers all the wildings of a husband's heart. He is so happy and comfortable that he begins to prefer happiness and comfort to everything else in the world, his wife included. Twenty years ago such a man was equally capable of heroism or crime. Now he is fit for neither. His soul is asleep."

If we regard this sentiment as the discontented growl of a bachelor or too much at variance with the metaphysical views we choose to entertain, yet we may incline to admit later that it is in fine accord with sincere psychologic doctrine. It is ultra materialistic, to be sure, but this is no embarrassment if the position be sound. We may not go so far as some of the older schools and attribute anger to the gall, joy to the spleen and love to the liver, but much is congenial in the theory of James and Lange that every emotion is the resultant of the organic impulses that converge to create it.

As far back as the seventeenth century, Descartes tried to show that a special set of organic operations prompted each of the six emotions he recognized as primary.

The psychology of that period was extremely primitive and the philosophers knew nothing whatever of glandular functions, but the prophetic hypothesis of Descartes has found excellent support among modern workers. Crile of Cleveland, Cannon of Harvard, Watson of Johns Hopkins and Angell of Chicago and others have shown that the pituitary, suprarenal, thyroid, thymus and similar structures are intimately confederated with the birth of the emotions.

The process works out quite simply. Let the gland or glands secrete more, or less, of their peculiar essence than usual, and the system at once shows the effect. Through deprivation, for instance, the cells in their glandular commonwealths are changed from complacent burghers to alert and excited warriors whose quickened functions rouse the faculties to a supreme efficiency. Tranquility is immediately transformed into conspicuous and dramatic movement. Fear, love, despair, joy, hope or ambition is produced and formally assumes control of the new activity. The individual is entirely at the mercy of such glandular impulses, for they are not to be restrained by wisdom or checked by morality.

Love is doubtless the most universally powerful of these glandular expressions, but it is reasonably certain that hunger, though merely a sensation, may easily rival the sexual instinct in the strength of its urge as it oft times exceeds it in bodily importance. Hunger and love are the two poles between which the world of humanity revolves. They are the primary functions of life. For the satisfaction of their imperious demands all vigor is acquired and all energy expended. In the attainment of these aims the brain weaves and works and sends shrewd inquisitors of thought in every auspicious direction. Chemical messages hurry to the brain from the viscera, emotions arise and mental orders for approprite action are sent out. It is need or desire that calls forth effort. A man neither craves nor dreams about the things he already has. Possession means calmness, a pleasure at rest, a desire satisfied.

Is a man starving? Visions of tables that groan under the weight of luscious viands will fill his mind by day and dominate his dreams at night. Is he thirsty? Fountains of crystal water will splash and tinkle for his expectant senses and the fateful mirage will loom before his feverish eyes. So the poet describes, not the things that are or have been, but rather the goals he burns most furiously to gain. The necessity of quenching innate personal passions, usually of glandular origin, inspires his song. When Mohammed wrote voluptuously about the black eyed houris of Paradise, he was still young and the blameless husband of an aged woman. Had he married a younger wife, the Koran would have suffered a marvelous change, for surfeit kills the imagination and satiety destroys art (Ellis). "If Matilda Wesendonk had eloped with Wagner in 1858, as he begged her to do," says Huneker, "Tristan and Isolde might never have been finished, or at all events, the third act would not have been what it is now."

Thus, while it is true that love is an intellectual and emotional stimulant of the first rank, yet it consistently obeys the law of satiety. In confirmation we may quote the case of de Fleury, whose patient, a well-known writer of great talent, confessed with truly French naïveté that whenever he experienced the ecstacy of love in the company of his mistress, he lost the power of composition for several days. Love has not been treated at length by either James or Lange, yet this emotion is really the best exemplar of their theory, for if, in a given instance, we suppress all the physiologic manifestations of the sexual

instinct, what have we left? Nothing. Not even the consciousness of a vague attraction.

The masterpieces of the world, all that is precious and best in sacred and profane literature, are the harvest of hungry souls, of souls ranging and questing but never satisfied. Yet they acquire their laurels only because they reproduce the intensity of the inspired authors at the time of their creation. This inspiration, whether spiritual or material is, to us, nothing but the symbol of the activating essence which arises in the cells and organs of the body. The product of a single gland, or an association of congenial influences, may engender an emotion, or it may happen that an excitement initiated by one organ will break the local barriers and involve other organs or glands, other functions or psychic states, through the medium of the sympathetic nervous system. When two or more glands or cravings act at the same time they may reinforce or neutralize each other, or the emotional field may become a confused tracery of induced currents, echoes and adumbrations through which utterance is difficult or impossible.

On the spiritual side, it is certain that most of the writings permanently bestowed in the world have been produced by visionaries of exceptional power, either mystic or otherwise. In these texts are many things which suggest a glandular confusion in conception or a lack of mental espionage in the exposition that is far from sufficient. Nevertheless, the obscurities and ambiguities are often accepted per se, as the signal evidences of a supernatural origin—the tenuous vestiges of a nebular creation. Do these works come from the clairvoyance of an alert and reasoning mind or are they dreams?

Dreams ordinarily originate in sleep, but there are waking hours wherein, under the intelligent control of the mental censor, a man transfers himself into artificial situations and reforms the world, or at least his relations thereto, according to his desires. After due residence in this fictitious edifice the artist seeks to give his dreams an outer and durable form. Lamb's "Dream Children" is a familiar and pertinent example. It is the wish fulfilment of Freud, but it is not subconscious, and it is far from infantile. Neither are these dreams sexual necessarily, though they may be, and often are, kindred to sex.

Not infrequently the tableau will be religious in type but strongly colored with sex, for "religion is the outgrowth of fear and love and so closely allied to sex," as Ribot says, "that this inexhaustible reser-

voir supplies or tinctures the major part of the protean religious manifestations. Each may, at appropriate times, reinforce, merge with or supplant the other." Religious exaltation is but a finer form of sex transport, and the visions of the seer pass up along the same electric filaments by which the visions of sexual ecstasy pass down. Spirituality is of necessity surcharged with sex for sexlessness is soullessness. The sex emotions however are joyous, sanguine and self-reliant, while the more dismal an emotion becomes the more truly is it religious. The solemnity of the Quaker, the melancholy of the Puritan and the depressive insanity of the early saints sufficiently illustrate the point.

All these manifestations, as well as their offshoots, direct and collateral, may arise, we repeat, from such states of consciousness as the physical conditions may create, either from within or without. An emotion of organic origin, or the sense of hunger, powerfully fixes the attention; the disturbing element is recognized and the faculties concentrate to quiet the clamor and bring about peace. The personality is cemented into a perfect mental and vegetative union which works energetically to satisfy a plangent need. Decision follows, and the end is attained with extraordinary facility.

The brain knows perfectly well that the body has a heart and a stomach, for every organ has a cerebral register, or what Carus calls a "psychic signature." The brain, however, is not merely the echo of internal sensations for it receives and reacts according to its disposition. "It centralizes indeed, but while taking its part in the concert, it puts its own mark on the impressions coming in" (Ribot). The brain may act as a center of exchange for the cells and transmit influences from one another, or it may happen that subtle intelligences will flow from one group of cells to others through directly communicating nerve filaments without cerebral intervention. Ultimately we may expect the exact tinge, merit and amount of impetus that each organ or function contributes to an emotion will be recognized and exactly differentiated, be it heart, kidney or stomach.

We may hope also that this disentanglement of the roots of the emotions will not only reveal psychologic states, but will permit us to interpret jealously the chemical and bacterial action taking place in the tissues and fluids of the body. Each emotion will then signalize some definite change which has markedly altered the quality of the

blood; a modification which, in turn, has brought about a specific reaction in the cells of the brain it nourishes. A contamination of the circulatory fluids inevitably perverts all organic and intellectual activity. The flora and fauna of the intestines, for instance, produce toxins that modify unmistakably the functional response of the various organs, especially the brain, to which the blood conducts them. Even more notable is the close alliance between the gastric secretions and pleasurable and painful states of the mind. Dyspeptics have a far from enviable reputation for being neither cheerful nor comfortable to live with. We cannot have strife and dissatisfaction in the stomach without a resultant unrest in the brain.

All physical agents that aid or diminish organic activity are capable ex officio of altering both nutrition and function. This we must admit and yet, says Ribot again, "feelings, emotions and passions have their primordial source in the organic, that is, in the vegetable activity. The states we know as needs, appetites, tendencies and desires are the direct result of every animal organization. They make up the true basis of emotional life." Even superficial reactions like heat and cold, sights and smells, bring about changes in secretion that beget emotions. These in turn produce mental pictures or visualizations. Every intense representation of an act tends to realize itself, for the vivid image is but the precursor of action.

The artist has representations that are exceptionally intense. He feels things violently. Ideas and associations are free flowing and pour forth abundantly from vital reservoirs. He dreams of orgies, love adventures, sanguinary dramas and virtues and vices of all kinds, but this imagery does not pass into physical action. The reason is obvious. The artist sees the incidents of his fancy, not as isolated units, but assembled and composite, and even as the sculptor sees a figure in stone so his brother wishes to perpetuate his dream in all its divine symmetry and perfectness. He objectivizes, therefore, by creating a work of art in which he lives and breathes and finds deliverance from a haunting idea. It is a period of exaltation in which the artist's design is executed with a maximum of energy and a minimum of consciousness. For the worker this is the best possible mood for production since the more intense the emotion becomes, the more attenuated is the intellectual element and, on the other hand, the clearer the perception, the weaker is the tone of feeling.

Thus far we have been concerned with the organic origin of the emotions and the method of their operation. The discussion is essential to our problem, but it is time to correlate these ideas and analogies with the subject of our thesis.

It may seem absurd to claim that an event so weakening as hunger could in any manner bring about results at all comparable to the soul-stirring effects of love, yet there is much testimony to its high value as an awakener of emotion.

We know that the consciousness of hunger is due to contractions of the muscles of the stomach, but whether this sensation acts as a direct excitant through glandular or cellular cravings or indirectly through the removal of intellectual control or breaks the envelop of generic inhibitions and thus releases ideas and subconscious states from the supervision of the censor, we have not learned. We are only entitled to report the clinical observation that in a condition of hunger the mind is so affected that associations, fantasies, dreams and inventions of rare quality flock across the threshold and pass from the penumbra into the light of day.

The physiologic facts of the process are described by Carlson of Chicago, who has studied the phenomenon exhaustively, not alone in the case of a peculiarly serviceable patient, but also more accurately in his own person. He informs us that while all the well-known gnawing sensations and pressure pains are present in the fasting individual, yet there is, in addition, a certain degree of excitability of the central nervous system. "The excitability is greatest when hunger is most acute. It is partly subconscious," he says, "and will depend upon the stability of the nervous system involved." This last statement is highly significant, as we have already shown. "Prolonged starvation," he continues, "appears at times to lead to heightened or abnormal cerebral activity as shown by the feeling of exaltation and by visual and auditory hallucinations. These phenomena are determined quite as much by the type of the emotional processes of the individual (intensity of interest?) as by the effects of starvation, since they are registered more frequently among religious ascetics than among the worldly minded."

Religious ascetics are usually extremely temperamental and therefore in this class, rather than among the "wordly minded," should the greater number of genuises be included. Their periods of inspiration

would doubtless equal in degree and possibly in frequency the transports of the ascetics in whom the elation that follows fasting is often confused with religious fervor. The ecstatics have abundantly recorded the principal features of their experiences under two heads: First, the restriction of consciousness to one overmastering center of association and second, the manifestation of rapture which is an emotional form of love, desire and pleasure of possession all combined. It is a focalization of consciousness accompanied by exaltation. In this happy state, the mind works with the greatest facility and the powers of expression are expanded wonderfully. It is another example of the cemented personality functioning in the highest degree of efficiency. The result, however, can never exceed the supreme possibilities of the individual

Carlson thinks the exaltation may be due to a depression of certain affiliated brain centers, which would correlate it with dreams, rather than to any actual increase in the excitability of the faculties. From another standpoint, it might be possible to explain the event as a temporary release from conventional inhibitions, or again, as a result of chemical changes in the blood induced by lack of nutrition. But whether it be a dream or an escape of the artist's true self from subliminal prisons or an impulsion due to altered metabolism is of minor importance, so long as the reality of the emotional upheaval is authenticated.

The after effects of Carlson's experience were also remarkable, and quite different from the tranquility, depression or even hebetude which follows the transports of love. "Both men," he says, "felt unusually well from the second day after breaking the fast." Carlson had the feeling that he had just returned from a holiday in the mountains. His mind was extremely clear and the amount of work accomplished, both mental and physical, exceeded the average. Thus, as frequently happens, the emotional wave persisted, or even increased, after the incitement had been withdrawn.

Carrington strongly corroborates Carlson. "In times of fasting," he testifies, "the senses are more alert, remarkably so and without exception. The eyes are bright and clear. Touch, smell and hearing are more acute, while taste becomes highly sensitized and more discriminating. The nervous system suffers least. Here, there is no loss of weight," for like sailors in times of stress who burn the woodwork

of the ship, the nerves feed on the less vital portions of the body. "Attention, memory and the power of association," he goes on to say, "are quickened and the ability to reason acquires an extraordinary brilliancy. Furthermore, there is an added appreciation of the more spiritual qualities like intuition, sympathy and love. The lack of nourishment energizes the will and clarifies the mind." Up to a certain point calculation and inductive reasoning is a matter of nutrition while emotion is not. When decision is due, the well nourished will deliberate and set forth his ideas logically. The underfed will emotionalize. When hunger is chronic or extreme, all the faculties are spurred to the utmost endeavor. It was not the mere absence of food that brought about the French Revolution, but through long deprivation came emotionalization with a resultant quickening of feeling and intellect. Moreover, as hunger pangs increase in pitch and persistence, the aggressive spirit becomes detached from larger loyalties and finds expression through personal and selfish channels. In this manner a vast outflow of emotion is generated by multiple organic cravings and accumulates until it is discharged by the catharsis of revolutions.

The full stomach, on the contrary, brings its own intellectual and social penalty. The assimilative acts take place in the inmost recesses of the tissues and organs. But what highways connect these processes with the cortex, that intensely vital layer on the surface of the brain? By what channels does the brain transmit its directive inquisitions or receive the echoes of the indolence, the haste, or the several modifications of the nutritive functions? Our information on this subject is not satisfactory, but it is clear that the business of nutrition depends especially on two elaborate systems of nerves, the great sympathetic and the pneumogastric, which are represented in some way in the outer layers of the brain.

Under the regulation of these nerves every particle of food must be worked up by the alimentary organs. It must undergo many complicated chemical changes, all of which demand energy from special structures and organs. When more food is taken in than growth and repair necessitate, there is a waste of force, a diversion of energy, and possibly so great a disturbance of the normal processes that systemic poisoning may occur. This poisoning may in turn reveal itself as a moral perversion or a mental irresponsibility. When all the organs

are functioning normally, the system is balanced and the brain works logically, according to the capacity of the individual.

Since only fifteen or sixteen ounces of proper food per day are necessary to support life, it is the rule to find overnutrition in civilized communities. Furthermore, anything that diverts the blood from an active organ interferes with or destroys that particular function. The brain, for instance, ceases to act when the blood is rushed to the aid of the struggling stomach—"that maid-of-all-work, battling against fearful odds." Digestion being accomplished finally, and at enormous expense, the transformed material is poured out into the system. In the overfed body the tissues are constantly choked, clogged or smothered by food products and fat is stored. Fat is waste, or excess, which has been deposited in the body instead of being eliminated. If through hunger we deprive the body for a certain time of its nutritional surplus, we give the eliminating organs a chance to unburden themselves and catch up. It is a true purification since the worthless matter is always first to go.

De Quincy, in his essay on Goldsmith, records an observation, derived possibly from his own experience, that "to be cloyed perpetually is a worse fate than to stand sometimes within the vestibule of starvation." Satiety means quiescence and stagnation. It is a discontinuance of spiritual evolution. Satiety curbs the questing soul. It restrains the normal desire of man to utilize all his faculties. With desire appeased, the imagination is either enfeebled or quenched, and the creative power of the mind is stifled.

We now come to an interesting phenomenon which is part of the dual endowment of man. Schopenhauer has remarked acutely, that "whatever direction we take in living our lives, there is always some element in our nature that remains unsatisfied and ever clamors for expression." This pent up passion may be released in some instances by representations of music or the drama, as Aristotle long ago suggested, but frequently, the inhibited aspiration demands a larger activity and the shackled soul-stuff struggles desperately for freedom.

This new path may be adventured in courses parallel or cognate with the one already traveled, like Gerome who, after a long and rarely successful career as a painter, laid aside the brush for the sculptor's chisel. More often, however, the issue of the feeling is antithetic to the individual's manner of life and apparently inconsistent.

The poet Yeats has noted and analyzed this curious occurrence and calls it the "development of the anti-self," which he explains as a "true self making its own experience." Mordell with the same idea names it "self-deception."

These bipolarized personalities are not infrequent among men of rich talent. Thus, we learn from Disraeli and Havelock Ellis that the most unchaste verse is often written by poets whose lives are blameless while, on the other hand, authors who have written most purely find their compensations in living impurely. Neurologists might call this a form of exhibitionism. Moore and Samuel Rogers are the examples Ellis chooses of the men who lived lives quite opposite to that of which they wrote, but such a list could be greatly enlarged. In fact, the licentious literature of the clergy might easily be an outlet rendered necessary by the austerity of their lives. In no other way could they escape the stiff-mindedness peculiar to chastity. Their unwonted repression inspires an over-emphasis on the nakedness of the flesh, while the conditions of their profession constrain them to a vicarious misbehavior. It is an old maid's insanity which, with Swift and Stearne at least, seemed to find physical as well as mental relief. Husymans remarks with his usual brilliant cynicism, that "much of this literature is so obscene that it could have been produced only by one who was chaste to asceticism." A more illuminating example may be found in the life of Corregio who, it is said, was timid, anxious, melancholy and penurious. He was always at work for his dependent family and yet he painted the Antiope, the Leda, the Io and the Paradise of Careless Joy in the nunnery at Parma.

If we may venture to alter a phrase of Yeats, we would say that Corregio's art was the compensating dream of a nature wearied by over-much renunciation. The word renunciation is the key to the problem of the conflict between life as it is and the starveling's dreams of what it should be. In life, we are forever giving up to circumstances, but in art, if it is worth while, the dreamer is inflexible. There is no mental or emotional renunciation but rather the fullest and most gratifying indulgence of personal expression. It is both a revolt and an ecstasy.

The artist achieves his ideals because they are the result of strenuous rebellion against the afflictions of his daily experience. In everyday life he longs insatiably for action as a mental and emotional outlet

for his ideas and his personality, but he receives only reaction, which is the physical response to a multitude of vexations, annoyances and denials. Thus it is the buried soul of man that strives for utterance, and its voice alone that finds immortality.

Corregio's true self, therefore, would be represented in the Paradise of the nunnery and in the search for passionate adventures among the nymphs of the forest. His nature, wearied by falsity to itself, threw off the masque and escaped, not from reality but into it. Such an escape is favored and actuated by physical demands like hunger and love, or by any other stress that leads the soul in desperation to break the chitinous inhibitions of caste and type and doff the livery of regimentation.

The greater the denial, the more vivid the dream; the fiercer the hunger, the clearer the vision. So we begin to understand how the gregarious Goldsmith, having failed to escape from himself by journeys about Europe, as described in the haunting lines of the "Traveler," came at length to believe neither happiness nor reality could exist for him except in the lowliest of villages and even that in process of abandonment. We begin also to appreciate how "a certain degree of abstinence is prerequisite to the formation of a breeding ground from which the dreams and images of desire may develop into the perfected visions of art."

But, you inquire, what is the connection between all this discussion and the subject of our thesis? Permit us to say, the connection is very close, for renunciation is repression and repression is—starvation. The habitual practice of chastity, sobriety, renunciation, poverty and hunger, leaves but one indulgence open to the artist and that is his dreams. "A mighty longing," contributes Huneker again, "is better for the birth of art than a world of facile happiness." But the longing need not be conscious. The feeling of existence is not found among the mass of men because with them it is continuous. When a man does not suffer, he does not normally think of himself, but let disease or privation appear with its attendant introspections, and he immediately discovers his ego.

Therefore, even if we do not meet with an engenderment, we may expect a liberation of artistry through hunger, a disengagement of the spirit from its inhibiting envelopes. To be sure, a temperament and a tendency must exist, for nothing of value can develop out of sterile

soil. We all know persons who have a gift for figures, music or painting which under proper conditions is capable of infinite expansion by exercise. In the same way any talent can be raised to the *nth* power through emotional strain or prolonged craving. We may cite, for example, the unhappy Keats who "was born with an unconquerable thirst for luxury," and we may rejoice to share in that sweet palliation of his disappointment and grief, which he drew from a glowing opulence of verse.

The case of Keats finds many repetitions among the devotees of the pen, and literature is regularly enriched by this apparent becripplement. Whether we consider the constant suffering of Pascal, which roused his emotions for the production of his famous "Meditations," or the misery of Thompson, which found escape in the "Hound of Heaven," or the gnawing hunger and despondency of Goldsmith, which gave us the lilt and lightness of the "Deserted Village," at all events, we cannot forget nor cease to be thankful for the literary artistry that comes when the brilliant but irresponsible faculties of genius have been focused and energized by disease or starvation. Without such stimulation Goldsmith might have been a simple curate in Westmeath rather than the famous author of "She Stoops to Conquer," and Thompson would have died without issue.

If humanity is advantaged, the individual must suffer. A genius is one who is doomed by his constitution and by his inalienable tendencies to bring forth his children in sorrow and alone, and throughout the years of whatsoever comfort he may secure, there will always remain on his flanks the scars of the parturitional lash.

The bluefish and the salmon, en route for the spawning ground, disregard all physical needs and make the journey fasting. Vocalists and athletes are well aware of the importance of an empty stomach when they wish to command their highest powers. The Hindoo, the Mongolian, the American Indian and the Jew, the ascetic of every tribe and generation has found in fasting an elevation of feeling so rapturous as to betoken a communion with Deity, and what matter if the hallucinations and visions that close his trial are sincerely accepted as tidings from the Most High? The stimulation is incontestible and the human soul is raised to new levels of perception. Elijah and Moses passed forty days without food, and the Redeemer himself

sought through fasting to bring his soul into free and unrestricted filiation with supreme spirituality. So also the painter, the philosopher or the poet may well purge his gross body of its impurities, being thereby assured that his mind will receive a myriad of new associations and contrasts. His imagination will be stimulated to higher and broader flights; he will be enabled to sublimate his tyrannous appetites; he will divert his corporeal excitation into emotional fields and produce an artistry which is at once a joy to the world and a bid for immortality.

The reveries and the waking dreams of man are normally the antithesis of his social perturbation. Goldsmith was a "child of the flesh," who yearned for a sequestered spot unconscious that he could not live therein. This was his affliction and also his redemption. The surface irritants were indispensable to the flowering of his genius. He existed in a world full of heartaches and antagonisms to which his emotions constantly reacted while his mind, with equal insistence, sought its own form of action—the desire being intensified by prolonged refusal. His art was the compensating dream of a life wearied by overmuch renunciation. In the "Deserted Village," the "Vicar of Wakefield," the "Traveller" and "She Stoops to Conquer," he sought an escape into reality from the restraints of circumstance. "He walked in no high altitude," as De Quincy says, "but at an elevation easily reached by the ground winds of calamity. From that cup of sorrow which is pressed upon all lips in some proportion, he was compelled to drink through the very tenure by which he held his gift," yet always with advantage to his accomplishment. But even so, are there not exceptions? Yes, for some there are whose powers transcend our human limitations but "it is only these Children of Paradise, the Miltons of our planet, who have the privilege of stars—thus to dwell apart." It is in solitude on his own particular pinnacle that the genius fasts and dreams his dreams. He is surrounded by spirits and assailed by demons. He hears the beating of their wings as they troop past. A lordlier form of terror hovers near, but grim and undismayed the prophet consecrates his powers to the purpose preordained. Withdrawn and silent, he broods over his destiny until his time is accomplished, then the shining vision springs into being, the deathless dream that stirs the souls of men to nobler aspirations and to deeds of high emprise. It is a vibrant call which restores the fainting heart and

forever renews the longing for endeavor on fresh planes by its mysterious and opportune purveyance.

But what of the human parent of this puissant offspring? Nothing. He has endured the swift mutations of joy and pain and elected his reward. His work is done. He seeks not, nor obtains, wordly sympathy. He has tasted divine ambrosia, and, feeling his quick relationship to celestial comrades, he would not change his one short day of royal ecstasy for the perdurable years of any man.

STANTON ABELES FRIEDBERG

1875-1920

Stanton Abeles Friedberg died May 27, 1920, as a result of complications from an attack of acute otitis media.

Dr. Friedberg was born in Chicago, Dec. 1, 1875. He received his preliminary education in the public schools of Leavenworth, Kansas, attending University of Michigan one year. He entered Rush Medical College in the fall of 1893 and graduated in 1897. He served one year's internship in the German Hospital of Chicago, and, after practicing general medicine for three years, he became assistant to the late Dr. E. Fletcher Ingals, beginning his lifework in the practice of otolaryngology. In 1905, he was made assistant in the department of laryngology at Rush Medical College, and in 1913 became assistant professor. He became a member of the staff of Cook County Hospital in 1906, and was made chief of the department of otolaryngology in 1913, holding this position until the autumn of 1919. He was made assistant to the attending laryngologist at the Presbyterian Hospital in 1909, and later became attending laryngologist.

Dr. Friedberg was justly proud of his service during the World War. In November, 1917, he was commissioned Major, M. C., and served eight months at the Base Hospital at Fort Sill, Oklahoma. At the end of this time he was sent to France with Base Hospital No. 85, serving eight months with the A. E. F., and was discharged May 1, 1919.

Dr. Friedberg was a member of the American College of Surgeons, the American Laryngological Association, the American Laryngological, Rhinological and Otological Society, and the American Peroral Endoscopists. He was also a member of the American Medical Association, the Chicago Medical Society, the Chicago Laryngological and Otological Society, as well as the American Academy of Ophthalmology and Otolaryngology.

His most noteworthy contribution to scientific medicine was work carried out while he occupied the position of consulting otolaryngologist at the Durand Hospital of the John McCormick Institute for Infectious Diseases. This work was in connection with diphtheria carriers, and he established the signal value of tonsillectomy in such cases. Since the death of his teacher, Dr. E. Fletcher Ingals, Dr.

STANTON A. FRIEDBERG

1875-1920

Friedberg has been recognized as the most capable operator in the field of bronchoscopy in this part of the country. He early acquired an interest in the history of medicine and wrote a number of papers on the history of his specialty. He acquired an unusual library of historical texts, engravings and reference books relating to otolaryngology.

He was married to Aline Liebman of Shreveport, La., in 1906, who survives him. He also leaves three children, Stanton, Jr., Jean, and Louise.

In Dr. Friedberg were combined the highest professional skill, a sense of integrity and fair dealing, and a genial personality which endeared him to his professional associates as well as to his patients. In his death the Institute loses one of its ablest members.

John Edwin Rhodes
Geo. E. Shambaugh

REPORT TO GOVERNORS OF THE INSTITUTE OF MEDICINE OF CHICAGO OF A COMMITTEE APPOINTED TO INQUIRE INTO THE QUESTION OF NECROPSIES IN THE HOSPITALS OF CHICAGO

A questionnaire and explanatory letter were sent to fifty-one hospitals in Chicago having 50 or more beds. Replies were received from 36 hospitals that have a combined bed capacity of 7,304. The fifteen hospitals from which no report was obtained have a reported bed capacity of 2,376. The figures in this report therefore cover about three fourths of the bed capacity of Chicago hospitals of 50 beds or more.

In the 36 reporting hospitals having 7,304 beds, there were 142,990 admissions in 1919, and 7,934 deaths. Permission necropsies were made in 789 cases and coroner's necropsies in 251 others. The later figure does not include coroner's necropsies at Cook County morgue. Omitting Cook County Hospital, 35 reporting hospitals had 4,405 deaths in which permission necropsies were made in 474 cases. Deducting coroner's cases, permission necropsies were obtained in slightly over 11 per cent. of cases.

The percentage of permission necropsies varied widely. Six hospitals reported over 20 per cent. of permission necropsies, 4 hospitals 10 to 20 per cent., 14 hospitals 1 to 10 per cent., 7 hospitals no necropsies, and 4 made indefinite or no statements as to necropsies. In one hospital with a percentage of 48.4, there were performed 30 per cent. of the entire number of 474 necropsies, and in the 6 hospitals reporting percentages of over 20, 56 per cent. of all the necropsies were made. Seven hospitals report that no permission necropsies were made; in these hospitals there were 91 coroner's necropsies out of a total of 251 for the 35 reporting hospitals.

All 35 hospitals report that they have rooms for the examination of the dead, of which 25 are regarded as adequate, 7 as fair and 3 as inadequate. Twenty-five of the hospitals have pathologists, of whom 15 are reported as full time, and 10 as part time. In 7 hospitals there is no pathologist, and examinations are made by a technician in 4, by

intern in 1, and no provision in 2. In one of these hospitals, which is noted for its surgical work, there were 217 deaths and 8 necropsies.

The attitude of the hospital administration toward necropsies is reported as favorable in 32, and one reports that there is no objection to necropsies. The attitude of the staff is reported as favorable in 29, indifferent in 4 and lax and careless in 1.

Before discussing reasons for the small numbers of necropsies, and the remedies therefor, it is desirable to note the difficulties reported by the hospitals themselves. In the order of frequency in which they were reported, the difficulties encountered in getting necropsies as given in the reports were: (1) religious scruples, (2) opposition of undertakers, (3) prejudice, (4) fear of mutilation of bodies, (5) lack of organized effort by the staff, (6) lack of contact between physician and relatives. One hospital, in which there were but 4 necropsies in 56 deaths, stated that no difficulties were encountered, a situation perhaps more hopeless than in most of the others.

Certain undertakers regularly stand in the way of necropsies; others are better informed, and cooperate with physicians in advancing medical science. The opposition of undertakers usually takes the form of an appeal to the ignorance of relatives and friends as to what is contemplated in a necropsy, and is effective frequently because the physician has failed to deserve and establish a close relation with the family.

There is something to be said for the undertaker, who has frequently found vessels essential to proper embalming unnecessarily damaged by the pathologist. Frequently, too, there is unnecessary delay in the signing of death certificates, and undertakers are required to wait at hospitals for from 2 to 4 hours for a signature which could have been obtained more promptly. This enforced waste of time adds to the irritation of undertakers, and tends to increase opposition.

While religious scruples present a serious obstacle to the obtaining of permission for necropsies, especially in some hospitals, and while prejudice and ignorance are often unsurmountable, the chief reason for the small number of necropsies in hospitals lies, however, in the indifference of the staff, whether admitted or not, and the lack of organized effort to improve the standard of diagnosis of the hospital. Failure to make an earnest effort to obtain a necropsy is often the natural sequence of failure to insist on good history, physical examination, laboratory examinations and progress notes. Continued neglect

Necropsies in Chicago Hospitals in 1919

Name of Hospital	Beds	Patients	Deaths	Necropsies: Permission	Necropsies: Coroner's	Per centage of Permission Necropsies	Part or Full Time Pathologist	Medical School Affiliation	Name of Pathologist
American	125	4,000	74	9	3	12.1	Full	None	M. C. Wells
Alexian Brothers	280	3,360	304	15	25	4.9	Full	None	Bro. Surgius
Augustana	200	4,190	217	8	6	3.7	None	None	
Chicago Fresh Air	104	307	89	Few	...	....	None	Northw.	
Chicago Lying-In	120	4,350	38	3	0	8.0	Part	Yes	
Children's Memorial	176	2,391	203	47	2	23.1	Full	Rush	R. S. Austin
Cook County	2,000?	27,819	3,529	315	?	8.9	....	....	Fred Stangl
Durand	60	733	41	10	0	24.4	Full	Rush	L. Hektoen
Garfield Park	60	1,462	60	0	0	0.0	Full	None	Josef Sielin
German Deaconess	60	2,654	96	2	14	2.0	....	None	W. H. Buhlig
Hahnemann	130	2,983	118	30	1	25.4	Full	Hahne.	W. H. Wilson
Home for Destitute and Crippled Children	115	1,096	7	0	0	0.0	....	Rush	
Illinois Central	110	2,305	92	3	0	3.2	Part	None	Mary H. Swan
Isolation	35	306	0	...	...	....	None	None	
Lakeside	85	2,006	90	0	10	0.0	Full	None	Herman Boettcher
Mary Thompson	75	1,861	56	4	1	7.1	....	None	
Mercy	354	5,813	191	25	6?	13.0	Part	....	
Michael Reese	440	9,123	368	33	?	9.0	Full	None	O. S. Schultz
North Chicago	90	1,935	46	Few	0	....	Full	....	Hirshberg
Norwegian-American	125	3,176	161	0	0	0.0	None	None	Technician
Park Avenue	64	450	40	0	12	0.0	....	None	Intern
Passavant	75	2,301	75	0	30	0.0	Part	None	Alvin Thompson
Peoples	40	1,030	57	0	22	0.0	None	Northw.	
Presbyterian	425	9,908	297	144	14	48.4	Full	Rush	B. F. Raulston
Ravenswood	50	1,425	44	6	4	13.6	....	None	J. J. Moore
St. Anne's	100	2,717	139	3	24	2.1	Part	Loyola	Geo. W. Wilson
St. Anthony	176	3,623	209	10	32 (inquest)	4.7	....	None	Fred Olentine
St. Bernard's	200	5,201	255	4	20	1.5	Part	None	J. J. Moore
St. Joseph's	166	4,224	149	32	10	21.4	Part	Rush	W. M. Burmeister
St. Luke's	400	9,527	295	52	?	17.6	None	None	E. F. Hirsch
U. S. Marine	130	1,036	28	6	2	21.4	....	....	Miss Eleanor Murray, Tech.
Washington Boulevard	85	2,395	61	5	12	8.2	....	None	C. E. Watts
Washington Park	110	4,000	93	3	5	3.2	....	None	De O'Connor
Wesley	275	6,681	251	20	15	7.9	Full	Northw.	F. R. Zeit
West Side	155	4,146	111	0	13	0.0	Full except 2½ days a week	None	L. R. French
Willard	110	2,756	60	0	4	0.0	Full and part	Loyola	B. H. Orndoff

of necropsies contributes to subsequent failures in diagnosis and in rational treatment. The postmortem examination confirms or disproves the clinical diagnosis and gives additional information of value to the clinician in subsequent practice, and the interest of the staff of a hospital in necropsies is one important index of its efficiency in treating disease and of the grade of work done in the hospital.

It is the belief of this committee that the alleged prejudice against necropsies is not so great as has been assumed, and that it is advanced as an excuse when the real reason is indifference on the part of the staff, including the pathologist.

In one large hospital in which there are a number of coordinate medical and surgical services, with approximately the same material and number of deaths, the number of necropsies varies directly with the interest manifested by the attending physician or surgeon and as a direct result of association, by their interns.

The physician who gives his patients and their relatives careful individual attention will in the event of a fatal outcome be accorded a much more kindly reception when he requests a necropsy than will the physician who has treated his patients by routine as so many cases. Devoted effort to save life makes the strongest appeal to relatives when a postmortem examination is requested.

RECOMMENDATIONS

The following recommendations are submitted:

1. That in view of the great importance of necropsies in improving the standards of medical practice, the Institute of Medicine take such steps as appear wise to assist hospitals to increase the number of necropsies. Discussion in hospital staff meetings of the subject of necropsies, the posting in a suitable place in the hospital of tabulations of the percentage of deaths in which necropsies were obtained, the elimination of unnecessary delay in the signing of death certificates for undertakers, the establishment of adequate laboratory facilities with a pathologist in active attendance at the hospital, closer cooperation between the pathologist and the physicians and surgeons on the staff, and above all, the encouraging of a more active personal interest in patients by the attending physicians and surgeons, whereby they will come in closer contact with the friends and relatives of patients, to the advantage of the patient, hospital and doctor alike, are among the ways

in which the number of necropsies may be increased, and the standards of hospital medical practice improved.

2. It is believed that the neglect of necropsies is largely a matter of inertia and failure to realize their value rather than of intent on the part of the staffs, and it is therefore recommended that this question be called to the attention of each hospital staff.

3. It is recommended that a further survey of necropsies in Chicago hospitals be made next year.

ERNEST E. IRONS, Chairman
D. J. DAVIS
J. P. SIMONDS
A. FRICK
ALLAN KANAVEL

ANNOUNCEMENTS

The Board of Governors has accepted an offer from a source that at present cannot be revealed, of $250.00 annually for a lectureship to be known as the Pasteur Lectureship of the Institute of Medicine of Chicago. The first Pasteur Lecture is published in this issue.

At the beginning of 1920 there were 215 active Fellows of the Institute. During the year 2 resignations, 2 deaths and the transfer of 3 Fellows to the nonresident roll caused a loss of 7, which, however, was offset by a gain of 29 new Fellows, leaving a total membership of active Fellows of 237.

The Treasurer's report for 1920 shows receipts of $9,427.96, and expenses $1,403.19. It is the policy to invest all accumulated funds in bonds and other securities, and at present the investments total $38,000.00.

New Fellows, if they wish, may obtain all back numbers of the Proceedings by notifying the Secretary.

The following were elected Fellows of the Institute since Jan. 1, 1920:

Channing W. Barrett
Albert M. Moody
Richard S. Austin
Edward H. Hatton
John Foote Norton
Douglas Singer
George H. Coleman
Frederick W. Gaarde
Walter H. Theobald
Robert Blue
Nathan S. Davis, III
L. C. Gatewood
James R. Greer
Selim W. McArthur
Harold E. Jones
Fred M. Smith
Alice Hamilton
Ruth Tunnicliff
Don P. Abbott
Robert J. Gay
William H. Burmeister
Robert P. Black
Frank W. Blatchford
Eugene Cary
John Favill
Hugh N. MacKechnie
Walter H. Nadler
L. J. Osgood
M. L. Goodkind

At the annual meeting of the Institute, Dec. 7, 1920, A. I. Kendall (to fill vacancy), D. J. Davis, S. J. Walker, and J. Gordon Wilson were elected governors.

At the annual meeting of the board of governors George H. Simmons was elected president of the Institute for 1921, and C. Judson Herrick, vice president. L. Hektoen was elected chairman of the board of governors, J. A. Capps, treasurer, and Ernest E. Irons, secretary.

TABLE OF CONTENTS

The Proceedings of the Institute of Medicine of Chicago are published at irregular intervals. For the present copies are distributed without charge to a limited number of libraries.

Address all communications in regard to the Proceedings to 637 South Wood Street, Chicago.